Federal Technology Alert

A series of technology guides prepared by the New Technology Demonstration Program

FEMP

FEDERAL ENERGY MANAGEMENT PROGRAM

U.S. Department of Energy

DoD EPA DOE SERDP

Strategic Environmental Research and Development Program

Improving Mission Readiness through Environmental Research

Solar Water Heating

Well-Proven Technology Pays Off in Several Situations

Solar water heating is a well-proven and readily available technology that directly substitutes renewable energy for conventional water heating. This Federal Technology Alert (FTA) of the Federal Energy Management Program (FEMP), one of a series on new energy-efficient technologies and renewable energy technologies, describes the various types of solar water-heating systems, the situations in which solar water heating is likely to be cost effective, considerations in selecting and designing a system, and basic steps for installing a system.

There are a variety of different types of solar water-heating systems, but the basic technology is straightforward. A collector absorbs heat from the sun and the system transfers that heat to water. That water is stored for use as needed, with a conventional system providing any necessary additional heating. A typical system will reduce the need for conventional water heating by about two-thirds, eliminating the cost of electricity or fossil fuel and the environmental impacts associated with their use.

Application

Solar water heating can reduce conventional energy use at any federal facility. Savings are likely to cost-effectively pay for system installation in three types of situations. First, any facility that pays high utility rates for its conventional water heating is a good prospect for cost-effective solar water heating. Many smaller facilities in rural areas (for example, a campground at a recreational area served only by electric power) are in this situation. Any of several mid-temperature solar water-heating technologies can serve well. Off-the-shelf packages are available and systems that operate passively without pumps or electronic controls are often appropriate in warmer climates.

Large facilities such as prisons, hospitals, and military bases with consistent need for large volumes of hot water are the second situation where solar water heating is apt to be cost effective. Even if conventional water heating costs are relatively low, economies of scale for large mid- or high-temperature systems can bring costs down to quite competitive levels.

Swimming pools are the third candidate use for solar water heating. Pool systems will often pay for themselves in just a few years, particularly for pools that are used year round. Relatively inexpensive low-temperature systems are quite effective and can either greatly reduce conventional pool heating bills or extend the season where heating was considered too expensive.

Software available from FEMP's Federal Renewables Program at the National Renewable Energy Laboratory (NREL) (303-384-7509) gives a preliminary analysis of whether solar water heating would be cost effective for your situation on the basis of a minimal amount of data. Federal Renewables Program staff or this Federal Technology Alert can help you select an appropriate type and size of system. Reliable off-the-shelf systems can be selected from the Directory of the Solar Rating and Certification Corporation (202-383-2570); there are also many other good systems available. Engineering services will be needed to design larger systems, but the FEMP Help Line (800-DOE-EREC) can provide manuals and software for detailed economic evaluation and for the Energy Savings Performance Contracting Program, which allows federal facilities to repay contractors for solar water-heating systems through bills for energy savings instead of paying for initial construction.

Technology Selection

The FTA series targets new energy-efficient technologies that appear to have significant untapped federal-sector potential and for which some federal installation experience exists. Many of the Alerts are about new technologies identified through advertisements for technology suggestions in the Commerce Business Daily and trade journals, and through direct correspondence in response to an open solicitation for technology ideas. This FTA describes a class of renewable energy technologies of known energy, cost, and environmental benefit, but still with substantial untapped potential for the federal sector.

Important criteria for selecting among the various types of solar water-heating systems include temperature of water needed, system size, degree of freeze and hard-water scaling hazard, and maintenance need. The table below summarizes those considerations.

Case Study

This alert describes examples in all three of the likely situations for cost-effective installations—high conventional water-heating cost, large, consistent hot-water use, and swimming pools—and presents a case study from the first situation. In lieu of electric water heating, the National Park Service is installing drain-back solar water-heating systems on two small and one large comfort station at its Chickasaw National Recreation Area in Oklahoma.

At a combined cost of about $22,000, the three systems will provide a total of about 136 MBtu (40,000 kWh) of energy per year to meet a hot water load that averages about 2800 gallons of hot water per day during the 7 months that the area is heavily used. Unlike most solar water heating, the Chickasaw systems will operate without conventional backup, meeting the full demand most of the time. The simple payback period for each of the systems is 9 years.

Implementation Barriers

There are no technological barriers to the use of solar water heating. Its cost-effectiveness varies by geographic area and type of use, but there are suitable technologies for all types of use in all parts of the country. Because it directly replaces conventional energy use, solar water heating will provide energy savings and environmental benefit to the full extent of its use. However, it will not always be cost effective from a straight financial perspective. We are not aware of any likely developments that could lower the cost of solar water-heating systems sufficiently to consistently compete with the low cost of natural gas. Solar water-heating is likely to be cost effective only if natural gas is not available, if consistent high-volume use provides economies of scale, and for swimming pool heating.

There are today an adequate number of good products and skilled system designers and installers. Planned inclusion of solar water-heating systems on the GSA purchase schedule should be quite helpful. Most federal facility managers should be aware of solar water heating, but may not realize its applicability to their facilities or may have heard of past problems from poor design or maintenance—unlikely situations today.

Solar Water Heating System Characteristics: Factors Useful in Selecting System Type for Particular Situations

		Suitable system size	Cost/ ft^2 for 40 ft^2 unless noted	Freeze tolerance	Hard-water tolerance	Maintenance need
Low-Temperature Systems						
Unglazed		for pools	\$10-\$25 (400 ft^2)	none	good	very low
Passive Mid-Temperature Systems						
Integrated collector		small	\$50-\$75	moderate	minimal	very low
Thermosiphon	direct	small	\$40-\$75	none	minimal	low
	indirect	small	\$50-\$80	moderate	good	low
Indirect, Active, Mid-Temperature Systems						
Flat-plate, antifreeze		small	\$50-\$90	excellent	good	high
		large	\$30-\$50 (30,000 ft^2)			
Flat-plate, drain back		small	\$50-\$90	good	good	high
Direct, Active, Mid-Temperature Systems						
Drain down		small		corrections being developed	minimal	high
Recirculating		small			minimal	high
High-Temperature Systems						
Evacuated tube	direct	small	\$75-\$150	good	minimal	high
	indirect	large	\$75-\$150	excellent	good	high
Parabolic trough		large	\$20-\$40 (30,000 ft^2)	excellent	good	high

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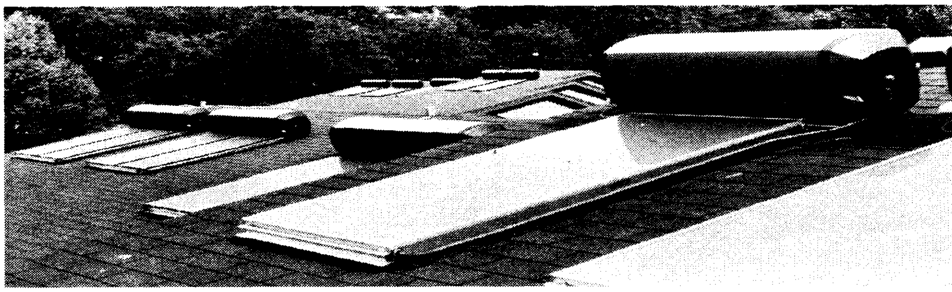


Thermosiphon solar water heaters on employee housing at Yosemite National Park

Abstract

Solar water heating is a renewable energy technology that is well proven and readily available and has considerable potential for application at federal facilities. Solar water-heating systems can be used effectively throughout the country and most facilities will have an appropriate near-south-facing roof or nearby unshaded grounds for installation of a collector. A variety of types of systems are available and suitable for many applications. For example, low-temperature unglazed systems can heat swimming pools and associated hot tubs or spas, saving money on conventional heating or extending the swimming season. In mild climates, passive systems without pumps or electronic controllers can provide low-maintenance hot water for facilities with limited or expensive utility service. High-temperature parabolic-trough systems can economically provide hot water to jails, hospitals, and other facilities in areas with good solar resources that consistently use large volumes of hot water. And active flat-plate systems can service any facility in any area with electric or otherwise expensive conventional water heating.

This Federal Technology Alert (FTA) of the New Technology Demonstration Program, one of a series of guides to renewable energy and new energy-efficient technologies, is designed to give federal facility managers the information they need to decide whether they should pursue solar water heating for their facility and to know how to go about doing so. Software available from FEMP's Federal Renewables Program at the National Renewable Energy Laboratory (303-384-7509) gives a preliminary analysis of whether solar water heating would be cost effective for your situation on the basis of a minimal amount of data.

This FTA describes the main types of solar water-heating systems available and discusses some of the factors that make the various types more or less appropriate for particular situations. It also points out the types of situations where solar water heating is most likely to be cost effective and gives examples for each of those situations. In addition, this FTA outlines the basics of selecting, evaluating, procuring, funding and maintaining a solar water-heating system. Sidebars highlight indicators that a system will be effective, tips for ensuring successful operation, and pointers for determining system data. A case study for a National Park Service facility includes economic evaluation data and bid specifications. References include solar water-heating collector manufacturers and system distributors and contacts for federal facilities that are using solar water heating.

Contents

About the Technology

An estimated one million residential and 200,000 commercial solar water-heating systems have been installed in the United States. Although there are a large number of different types of solar water-heating systems, the basic technology is very simple. Sunlight strikes and heats an "absorber" surface within a "solar collector" or an actual storage tank. Either a heat-transfer fluid or the actual potable water to be used flows through tubes attached to the absorber and picks up the heat from it. (Systems with a separate heat-transfer-fluid loop include a heat exchanger that then heats the potable water.) The heated water is stored in a separate preheat tank or a conventional water heater tank until needed. If additional heat is needed, it is provided by electricity or fossil-fuel energy by the conventional water-heating system. By reducing the amount of heat that must be provided by conventional water-heating, solar water-heating systems directly substitute renewable energy for conventional energy, reducing the use of electricity or fossil fuels by as much as 80%.

Today's solar water-heating systems are well proven and reliable when correctly matched to climate and load. The current market consists of a relatively small number of manufacturers and installers that provide reliable equipment and quality system design. A quality assurance and performance rating program for solar water-heating systems, instituted by a voluntary association of the solar industry and various consumer groups, makes it easier to select reliable equipment with confidence. After taking advantage of possible use-reduction measures (see box at right), federal facility managers should investigate installing solar water-heating systems.

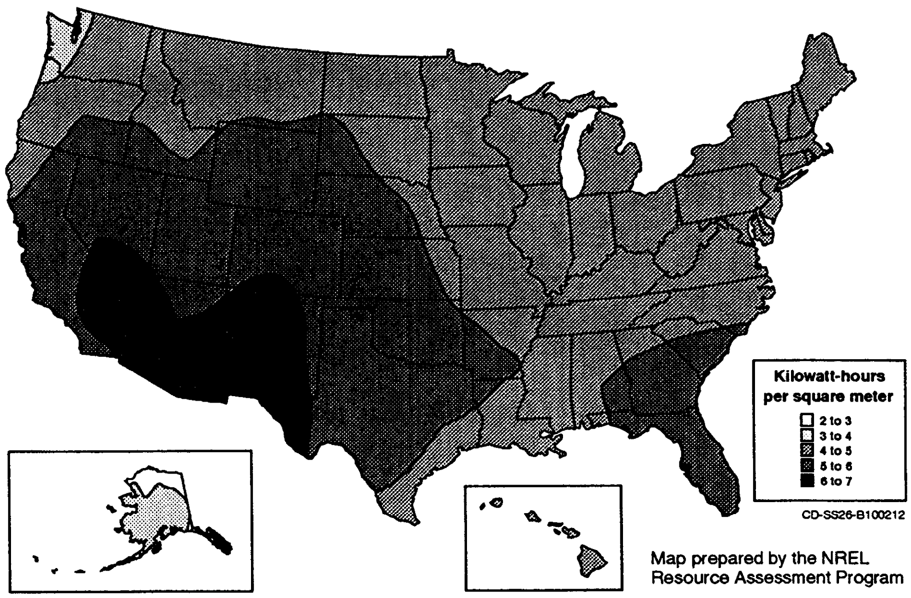


Fig. 1. Average Daily Global Solar Radiation (on a south-facing flat surface tilted at latitude, resource for all but parabolic troughs). Solar water heating can be used effectively throughout the country. Available solar radiation is the most important, but not the only factor for cost-effective use.

Application Domain

Water heating accounts for a substantial portion of energy use at many federal facilities. Nationwide, approximately 18% of energy use in residential buildings and 4% in commercial buildings is for water-heating. Federal facilities with large laundries, kitchens, showers, or swimming pools will likely devote even more energy to water-heating. Solar water-heating systems can efficiently provide up to 80% of the hot-water needs of many federal buildings—without fuel cost or pollution and with minimal operation and maintenance expense.

Solar water-heating systems are most likely to be cost effective for facilities with water-heating systems that are expensive to operate or with operations such as laundries or kitchens that require large quantities of hot water. A need for hot water that is relatively constant throughout the week and throughout the year, or that is higher in the summer, is also helpful for solar water-heating economics. On the other hand, hard water is a negative factor,

First Things First

As a rule, conservation is the most cost-effective way to reduce water-heating bills. For example, a low-flow showerhead costing $9 saves $22 for 275 kWh of energy per year for a five-month payback. Other examples of hot-water saving measures include faucet aerators, timed or optical-sensor faucets, water-saving clothes washers, dishwashers or other appliances, water heater insulation, lower-setting or timed water heaters, and swimming pool covers. These energy efficiency measures are all compatible with solar water heating, and often reduce the size of the systems needed. Reducing hot-water use saves on water and sewage as well as energy. For more information, ask the FEMP Help Line (800-DOE-EREC) about the Water Conservation Program.

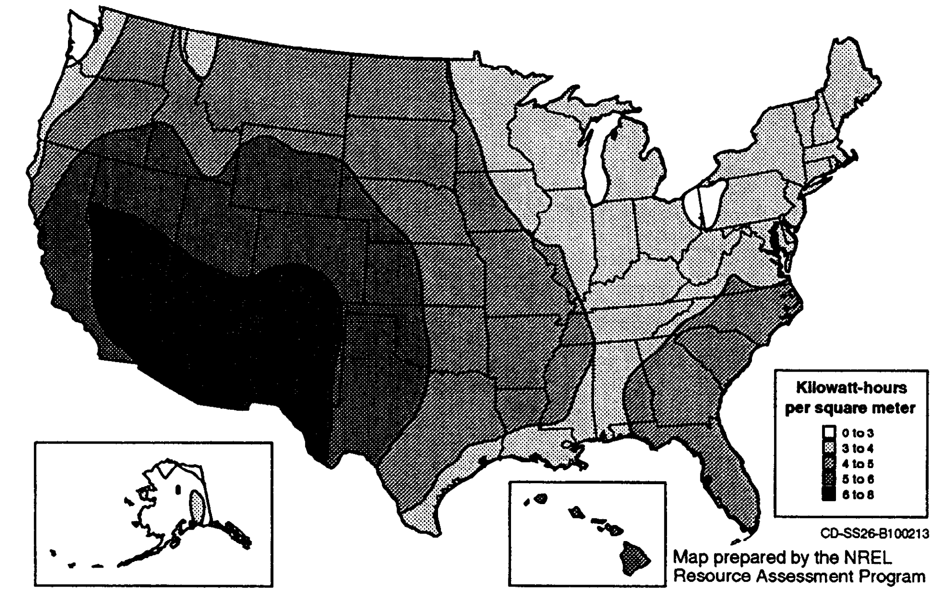


Fig. 2. Average Daily Direct Normal Solar Radiation (on a tracking surface always facing the sun, resource for parabolic trough). Parabolic-trough solar water heating can be very effective for large systems, but is best suited to areas with high direct solar radiation.

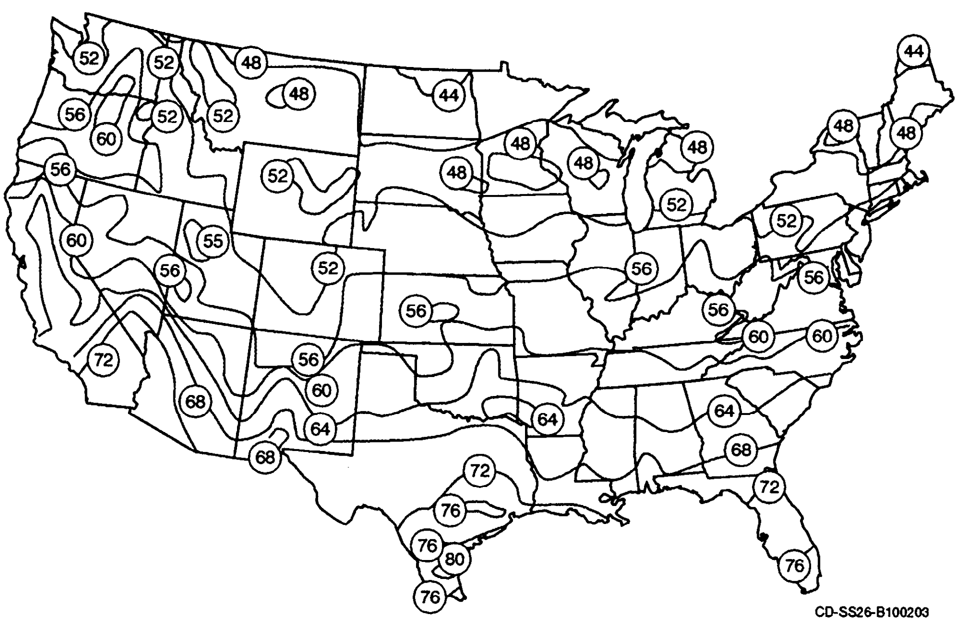


Fig. 3. Ground Water Temperature in °F in Wells Ranging from 50′ to 150′ Depth. Water supply temperature is also an important factor for solar water heating. Cost-effectiveness is better if water must be heated from a colder starting temperature.

particularly for certain types of solar water-heating systems, because it can increase maintenance costs and cause those systems to wear out prematurely.

Solar water heating can be used effectively throughout the country. The dominant factor in determining effectiveness for solar water heating is the available solar resource (see Figures 1 and 2), but do not dismiss the possibility of using solar water heating because the facility is in a cloudy area. Other factors are also quite important and solar water heating works better than might be expected in areas with lesser solar resources. Cold water supply temperatures (see Figure 3 and Appendix A) increase system efficiency because until the fluid being heated reaches higher temperatures, it loses less heat to the surroundings. Cold air temperatures hurt solar water-heating

Recent Track Record Excellent

The majority of existing solar water-heating systems were installed in the 1980s when private parties were eligible for a 40% federal residential energy tax credit or a 15% business energy tax credit incentive. (There is currently only a 10% business energy tax credit.) Although solar water heating had certainly already been around for a while, there was not yet a mature industry prepared to handle large-volume sales and installation. In the rush to take advantage of sales spurred by the tax incentives, many systems were poorly designed or installed or inadequately maintained. This earned solar water heating a bad reputation that is not deserved by today's industry. Solar water-heating systems are now well proven, installers are highly professional, and the industry has demonstrated an excellent track record in recent years. (See "Suppliers" on page 21 for list of manufacturers of collectors and distributors of systems.) With careful selection of the right system for a particular situation, today's solar water-heating installations are largely free of problems.

Although some solar water-heating systems from the 1980s were not as well designed or installed as they should have been, the majority are still delivering energy with little or no maintenance. A 1992 survey of 185 residential systems in Colorado, for example, found that 65% of the systems were functioning properly and that half of those with problems could be repaired for less than $150. The 1980s was also the most active period at federal facilities with 718 systems installed during or shortly after 1981 through the Solar in Federal Buildings Program. If you have an older existing system—functioning or non-functioning—it would be well worthwhile to have it examined for possible improvements or reactivation.

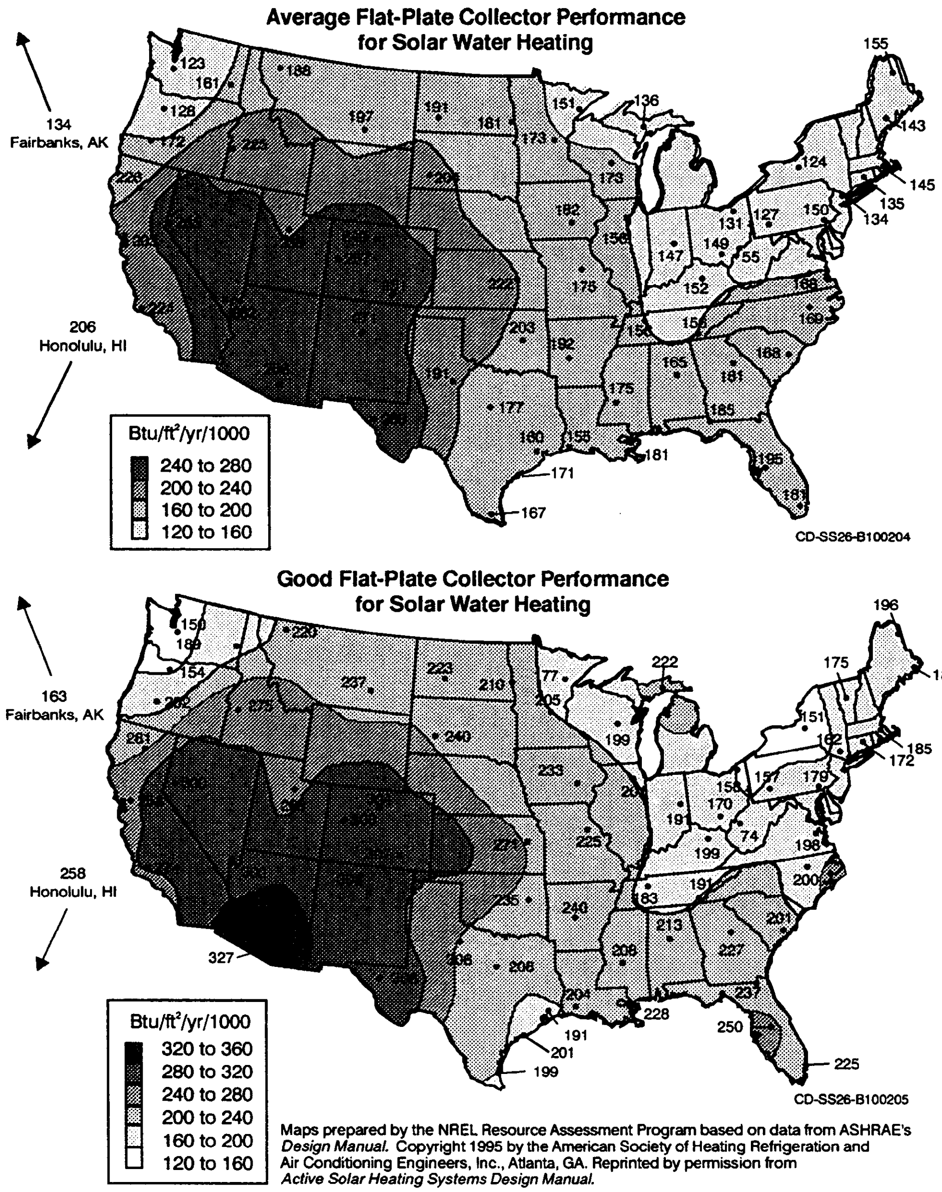
performance by increasing loss of heat from the collectors to the air. Figure 4 shows the performance that can be expected by average and good solar collectors, respectively, in various parts of the country.

Benefits

By tapping available renewable energy, solar water heating reduces consumption of conventional energy that would otherwise be used. Each unit of energy delivered to heat water with a solar heating system yields an even greater reduction in use of fossil fuels. Water heating by natural gas, propane, or fuel oil is only about 60% efficient and although electric water heating is about 90% efficient, the production of electricity from fossil fuels is generally only 30% or 40% efficient. Reducing fossil fuel use for water heating not only saves stocks of the fossil fuels, but eliminates the air pollution and climate change gas emission associated with burning those fuels.

Energy-Saving Mechanism

Although solar water-heating systems all use the same basic method for capturing and transferring solar energy, they do so with such a wide variety of specific technologies that one almost needs to learn a whole language of terms for distinguishing different collectors and systems. The distinctions are important though, because various water-heating needs in various locations are best served by certain types of collectors and systems. Systems can be either active or passive, direct or indirect, pressurized or nonpressurized. (*Note:* the terms open-loop and closed-loop are frequently used to distinguish between direct and indirect systems, but technically their meaning is more equivalent to nonpressurized and pressurized. To avoid confusion, we will not use them here.)



Maps prepared by the NREL Resource Assessment Program based on data from ASHRAE's *Design Manual.* Copyright 1995 by the American Society of Heating Refrigeration and Air Conditioning Engineers, Inc., Atlanta, GA. Reprinted by permission from *Active Solar Heating Systems Design Manual.*

Fig. 4. Important factors for solar water-heating performance include solar resource, air temperature, water supply temperature, and collector efficiency.

Types of Systems

The most frequently used systems for large facilities, *antifreeze* systems, are active, indirect systems. *Active* solar water-heating systems use pumps to circulate a heat-transfer fluid between the collector and the storage tank. *Indirect* active systems use a heat exchanger to transfer heat from the circulating fluid to the potable water. Antifreeze systems circulate a nontoxic fluid, usually propylene glycol, through the collector. See Figure 5 or Appendix H.

Even in freezing climates, however, water is often the heat-transfer fluid of choice. This is because water has excellent heat-transfer properties, it is noncorrosive and highly stable, and it is less expensive. The need to prevent the system from freezing is, of course, the trade-off for using water as the heat-transfer fluid. The *drain-back* system does this by totally draining the heat-transfer fluid out of the collector loop whenever the pump is off, which is whenever the water in the collector is not hot enough to heat the potable water, and therefore also whenever there is any freeze danger. See Figure 6 or Appendix I. In contrast to most indirect systems, which are *pressurized,* many drain-back systems use a *nonpressurized* heat-transfer-fluid loop. Nonpressurized systems may use plastic or site-built tanks that are less expensive and more durable than pressurized

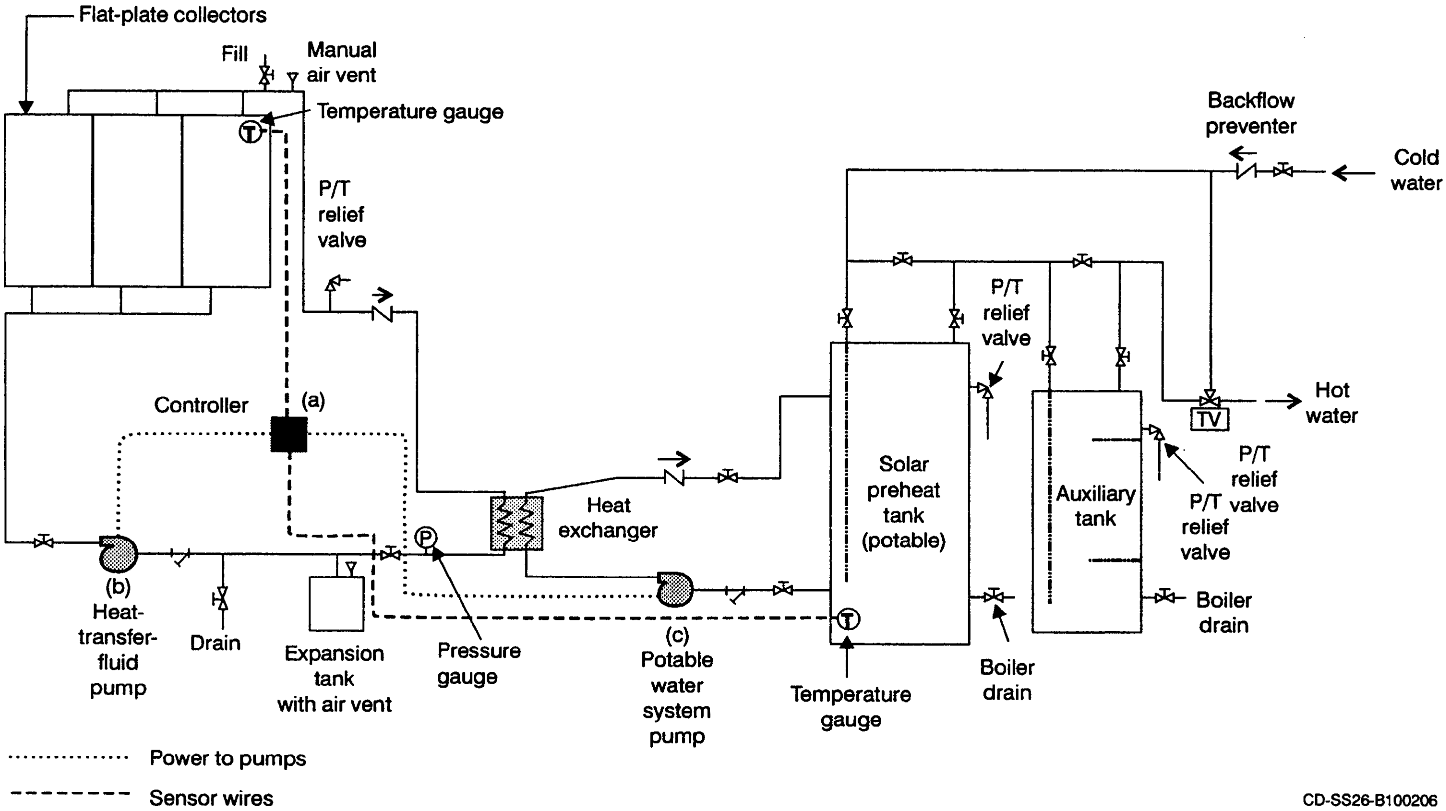


Fig. 5. Active, Indirect, Two-Tank Antifreeze System

metal tanks. Evaporated water must be replaced and being open to the air poses greater corrosion potential, but for a large system there may be significant savings with a nonpressurized tank.

Direct active systems run the potable water to be consumed directly through the collector. Because they do not require a heat exchanger, they average 5%-10% greater efficiency, but they must, in turn, activate special mechanisms to prevent the system from freezing. When control systems sense potential freeze conditions, valves on *drain-down* systems shut the service water off from the collector loop water and allow the collector loop water to drain out into a sump or down a drain. *Recirculating* systems respond to freeze danger by pumping heated water through the collection loop. Although freezing problems have been documented with both of these direct systems in the past, a newly designed valve for the former and careful choice of the right situations to use the latter may prevent those problems. Hard water is particularly troublesome for direct systems, because scale deposits that form in the collectors can reduce efficiency, increase the likelihood of freeze damage by restricting flow, and eventually shut down a system.

For smaller systems in mild climates with modest freeze threat, *passive* systems are also a viable option. Passive systems do not require pumps or electronic controls, greatly simplifying operation and maintenance, making passive systems very attractive for certain situations. These are, in fact, the most commonly used system types in climates with modest freeze threat. However, because they usually store water outside at or near the collector, these systems are subject to greater heat loss. In cold climates particularly, this heat loss reduces the efficiency of the system in terms of the percentage of the solar energy originally absorbed that is eventually used.

Of the two main types of passive systems, *integrated collector systems* (ICS) store the heated water inside the collector itself. *Thermosiphon* systems have a separate storage tank directly above the collector. In direct thermosiphon systems, the heated water rises from the collector to the tank and cool water from the tank sinks back into the collector. In indirect thermosiphon systems, heated antifreeze rises from the collector to an outer tank that surrounds the potable water storage tank and acts as a heat exchanger (be sure meets any code stipulations about double-wall heat exchangers for separation from potable water). See Figure 7 or Appendix J. In both ICS and thermosiphon systems, good insulation of the collector or tank helps prevent freezing and heat loss at night. The critical links, however, are the pipes connecting the collector or tank to the service water inside the house. Depending on pipe size and insulation, they can withstand temperatures that are only so far below freezing for only so long, so the geographic areas where these passive systems may be safely used must be carefully calculated. Hard water is again a concern. Also, most roofs will support the substantial weight of the water storage, but this consideration cannot be ignored in adding a system to an existing structure or in designing a new facility.

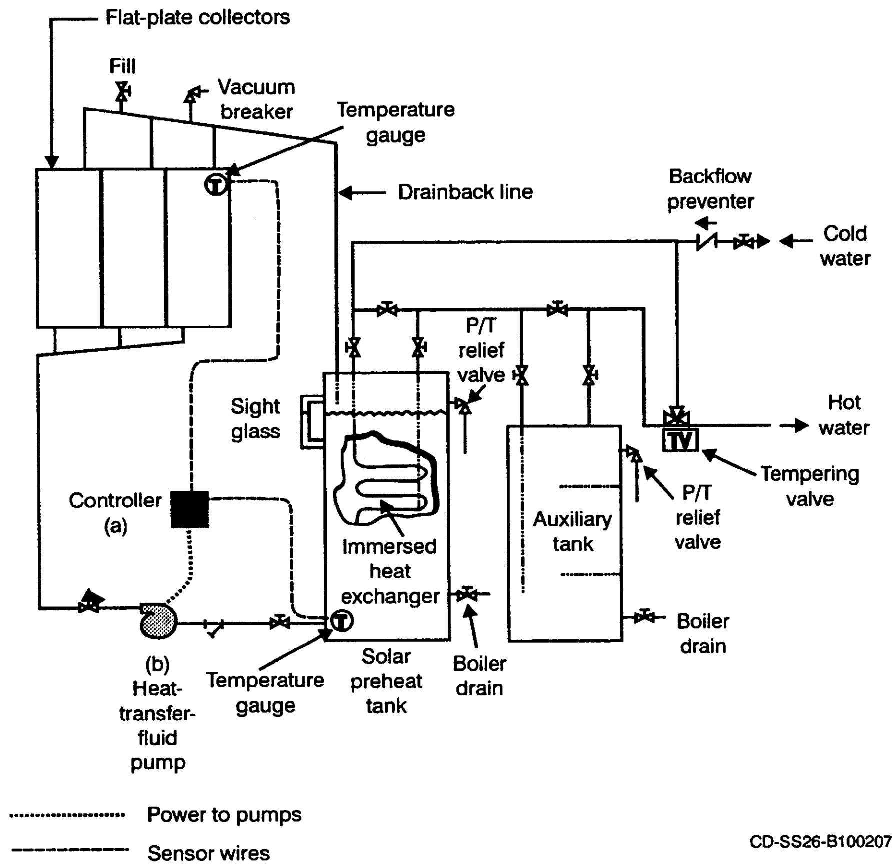


Fig. 6. Active, Indirect, Two-Tank Drain-Back System

Types of Collectors

The principal component of a solar water-heating system—the collector—can be low-temperature, mid-temperature, or high-temperature. The *glazed, flat-plate* collectors most commonly used for commercial or residential domestic hot water are classified as *"mid-temperature"* collectors, generally increasing water temperature to as much as 160°F (71°C). As shown in Figure 8, flat-plate collectors consist of an insulated, weather-tight housing or box, a clear glass or plastic cover glazing, a black absorber plate, and a system of passages for the heat-transfer fluid to pass through the collector. Special coatings on the absorber maximize absorption of sunlight and minimize re-radiation of heat. Gaskets and seals at the connections between the piping and the collector and around the glazing ensure a water-tight system.

"Low-temperature" collectors, which generally increase water temperature to as much as 90°F (32°C), are less expensive because they consist simply of an absorber with flow passages and have no covering glass (glazing), insulation, or expensive materials such as aluminum or copper. These collectors are less efficient in retaining solar energy when outdoor temperatures are low, but are quite efficient when outside air temperatures are close to the temperature to which the water is being heated. They are highly suitable for swimming pool heating and other uses that require only a moderate increase in temperature and are most commonly used in warmer areas. For the last several years, they have been the most frequently installed collectors. In warm climates, low-temperature collectors are sometimes used in hybrid systems that heat a pool in the winter and supplement domestic water-heating in the summer, when pool heating is not needed.

Large federal facilities or ones with quasi-industrial operations such as laundries may be able to efficiently use more sophisticated *"high-temperature"* collectors. Although they are also used in mid-temperature systems, *evacuated-tube* collectors can be designed to increase water/steam temperatures to as much as 350°F (177°C). They may use a

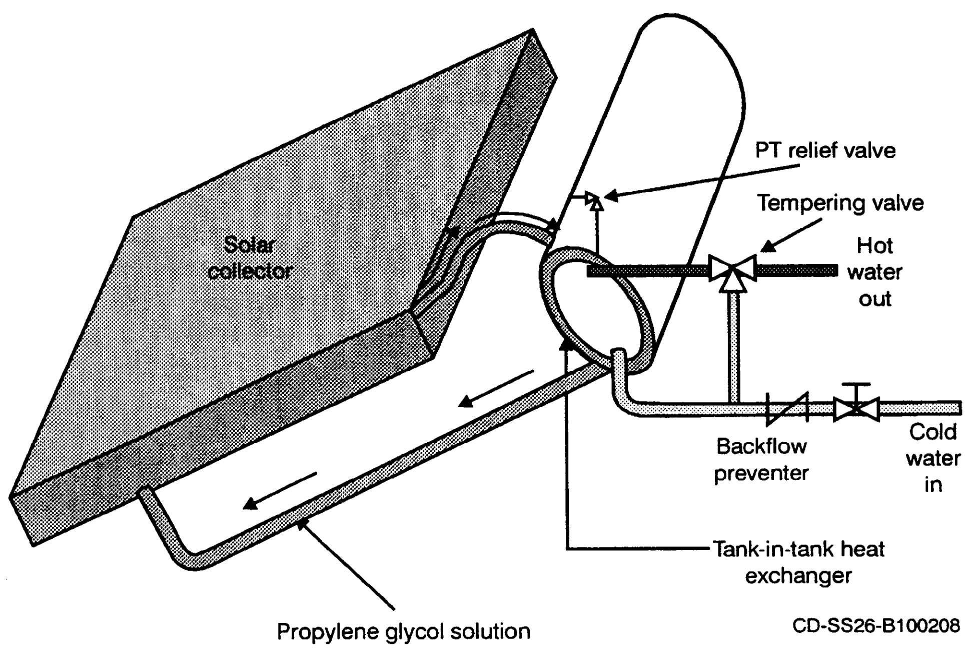


Fig. 7. Passive, Indirect Thermosiphon System

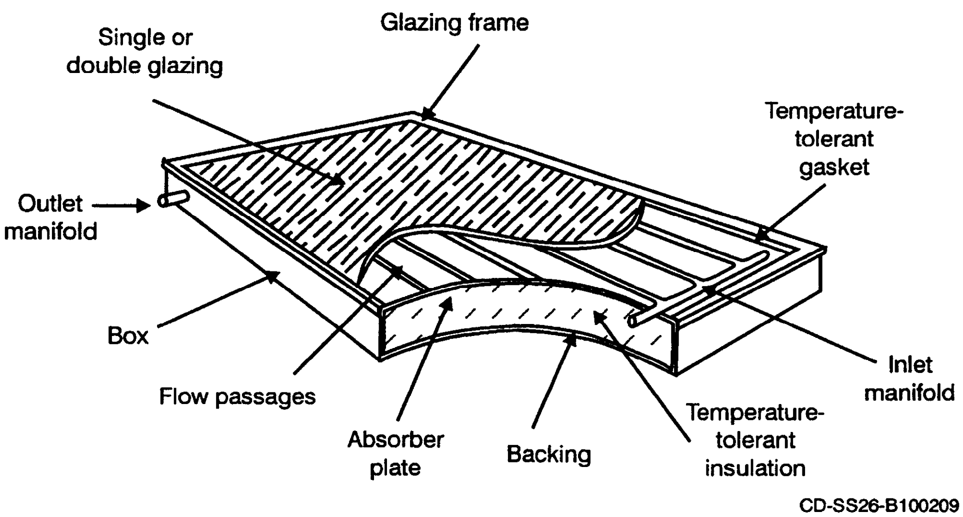


Fig. 8. Flat-Plate Collector

variety of configurations, but generally encase both the absorber surface and the tubes of working fluid in a tubular glass vacuum for highly efficient insulation. See Figure 9. Evacuated-tube collectors are the most efficient collector type for cold climates with low-level diffuse sunlight. They can be mounted either on a roof or on the ground, but they need to be protected from vandalism and can be damaged by hail or hurricanes.

Parabolic-trough collectors use curved mirrors to focus the sunlight on a receiver tube (sometimes encased in an evacuated tube) running through the focal point of the mirrors and can heat their transfer fluid to as much as 570°F (299°C). See Figure 10. Because they use only direct-beam sunlight, parabolic-trough systems require tracking systems to keep them focused toward the sun and are best suited to areas with high direct solar radiation. See Figure 2. Because they are particularly susceptible to transmitting structural stress from wind loading and require large areas for installation, parabolic-trough collectors are usually ground mounted. For electrical generation or industrial uses that require very high temperatures (greater than 392°F [200°C]), a heat-transfer fluid such as an oil is used, but depending on the degree of danger of freezing, antifreeze or water is used in the heat-transfer loop for domestic water-heating systems. Parabolic-trough collectors generally require greater maintenance and supervision and particularly benefit from economies of scale, so are generally used for larger systems.

System Design

System design for solar water-heating systems seeks to effectively combine solar water-heating with conventional water-heating. Rather than trying to store enough hot water to last through a long period of cloudy weather, solar water-heating systems generally have conventional water-heating systems as backup. Exceptions, such as the Chickasaw National Recreation Area systems cited later as a case study, are situations in which a lack of hot water for a few days is acceptable and the expense of conventional backup is not justified. Typically, a conventional hot-water heater draws preheated water from the solar water-heating system storage tank. If that preheated water is not hot enough, the conventional water heater operates as it would if it were starting with cold water and further heats the water until it reaches its set delivery temperature. Occasionally, the solar-heated water (up to 180°F [82°C]) is too hot for safe use, so it is mixed with cold water in a tempering valve.

As shown in Figure 5, a typical active, indirect solar water-heating system consists of one or more parallel-connected glazed flat-plate collectors, a storage tank, a heat exchanger, piping and valves for the heat-transfer fluid and for the potable water, pumps, and controls. Whenever the temperature of the water in the collector exceeds that of the stored water by more than a certain amount (usually about 12°F [6°C]), the "controller" (a) turns on both pumps (b and c). The heat-transfer-fluid system pump (b) circulates heated antifreeze from the collectors to the heat exchanger (where it transfers heat to the potable water) and back to the collectors. The potable water system pump (c) circulates cool water

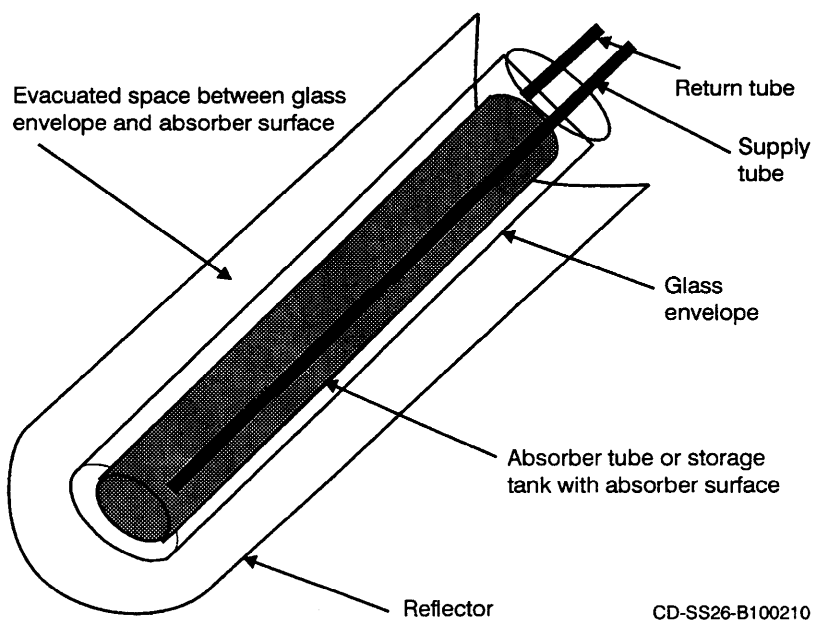


Fig. 9. Evacuated-Tube Collector

from the bottom of the storage tank to the heat exchanger for heating and then back to the top of the storage tank. (Instead of having a separate heat exchanger unit, the heat-transfer fluid may "wrap around" the potable water storage tank either with piping or with a surrounding outer tank.) As water is used from the conventional hot-water tank, it is replaced by solar-heated water from the top of the storage tank. Inlet water from the domestic supply system flows into the bottom of the storage tank to keep the system full.

Alternatively, a single storage tank may be used. A common single-tank design disconnects the heating element(s) from the lower portion of a conventional electric water heater. When the solar water-heating system is operating, it draws cold water from the bottom of the tank and returns the heated water to the top. If the solar heating does not have the water hot enough, the conventional heating elements in the top of the tank bring the water up to the desired temperature. Although not used much in this country, another single-tank design uses a rapid booster or "tankless" heater in the water line as it leaves the tank to provide additional heating upon demand, if needed. This option avoids maintaining the whole tank at the desired temperature as most conventional water heaters do, minimizing standby losses. Some two-tank systems add a second direct pipe connection with appropriate check valves between the two tanks to increase heat flow from the solar storage tank to the conventional tank. If the solar storage tank is hotter than the conventional water service tank, hot water flows by convection into the service tank, even when there is no draw on the system.

The most cost-effective size for a solar water-heating system will often be one that is just sufficient to meet the full summer demand and that meets approximately two-thirds of the year-round demand. Including enough capacity to meet more of the winter demand reduces cost-effectiveness both because excess capacity is wasted in the summer and because it is increasingly difficult to serve each additional portion of the winter demand with the reduced solar resource. The most cost-effective size can vary widely with specific circumstances, however, and for commercial building systems especially, it is sometimes best to plan to supply considerably less than two-thirds of hot-water use. The key factors in determining the most cost-effective size for a system are the type and cost of conventional fuel and the cost of the solar water-heating system to be installed.

Warren Gretz, NREL/PIX327

Fig. 10. Parabolic trough solar water-heating system for Adams County, Colorado, Correctional Facility

Good records of past hot-water use help greatly to plan an effective solar water-heating system, and it is easy to install a water meter on the incoming line to a hot-water heater. Water use can vary quite substantially, but for new construction, or if your uses of hot water are relatively "standard," there are "rules of thumb" to estimate hot-water requirements for various building uses. The handbook guideline for residential use, for example, is 20 to 30 gallons per person or 65 gallons per household per day. (Note, however, that some more recent studies have found average use as low as 25-35 gallons per household per day.) For office buildings, you can expect hot-water use of 0.5 gallon per person per day. (The standard reference for projecting hot-water use is the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. [ASHRAE] *Applications Handbook*, Chapter 44.)

The circumstances for specific large facilities may vary considerably, but for small systems, a general rule of thumb is to have storage roughly equal to one day's hot-water use. In a location with average available solar energy, you will need approximately

A Few Prescriptions for a Successful Solar Water-Heating System

- Size the system conservatively, probably to meet at most two-thirds of total hot-water use
- Pay careful attention to freeze and corrosion protection
- Use professional advice and prepare the bid package carefully, using an engineering or design firm or contractor that has experience in designing solar water-heating systems
- Ensure that you will have a facility manager committed to renewable energy and the project
- Commit to doing simple system checks a couple times per year and doing all necessary maintenance

0.5 to 1.0 square feet of flat-plate collector per gallon of storage tank. The daily pattern and consistency of hot-water consumption is also an important consideration for determining the size of collector and storage area needed. Uses that demand hot water mostly during the day (laundries, lunch service, or car washes, for example) will require relatively less storage than uses such as showers for which the heaviest demand occurs at night or early in the morning.

Installation

Solar collectors can be mounted on the roof of a building or on nearby grounds. For year-round uses, the most efficient orientation for the collector is facing south, tilted at an angle about equal to the latitude of the site. (The latitude plus 15° maximizes wintertime heat collection and latitude minus 15° maximizes summertime heat collection.) Collectors can be tilted to the proper orientation with mounting racks. For cost savings and aesthetic reasons, however, they are increasingly being laid flat against pitched roofs. If the orientation is at all close to optimal, the sacrifice in available energy is usually quite modest. For Denver, Colorado, for example, with a tilt of latitude minus 15°, mounting the collectors as much as 45° off of southern orientation loses at most 10% of available solar energy. Similarly, with a true southern orientation, you can mount collectors at up to 25° off latitude tilt with only 10% loss. Solar resource information for Boulder, Colorado, is presented in Appendix B as an example of available data.

Incorporating solar water-heating systems in new construction has the advantages of ensuring that there is an appropriate roof for collector placement, allowing for aesthetic design, and reducing installation costs. If the builder, architect, or engineer is used to working with solar water-heating, it can also save on design cost. But, almost any building can incorporate a solar collector retrofit. It is relatively easy to add a solar water-heating system to an existing facility and the economics will be nearly as good.

There are generally relatively few special regulations to consider in installing solar water-heating systems, but there are pertinent building, mechanical, and plumbing codes. Areas with special building regulations because of earthquake or hurricane danger, might have structural requirements limiting the weight or type of equipment that can be placed on a roof. Some local codes for residential or commercial areas regulate the attachment of collectors to roofs or walls. A few jurisdictions require rigorous separation between the heat-transfer fluid and the potable water in closed-loop systems that could rule out single-wall heat exchangers. Besides regulations such as these, systems need only comply with standard plumbing and local building codes.

Numerous manufacturers make quality solar collectors and solar water-heating systems. In addition to checking out the various manufacturers, one way to ensure that your system meets generally applied standards is to install an SRCC-certified system. An independent, nonprofit organization created by organizations representing solar equipment manufacturers, state governments, and consumers, the Solar Rating and Certification Corporation (SRCC) has instituted a quality assurance and performance rating program. As of December 1995, the SRCC had certified 3 unglazed collectors and 60 glazed flat-plate collectors made by a total of 12 different manufacturers, plus 78 total solar water-heating systems made by 12 different manufacturers. The SRCC certification process also ensures that health and safety issues have been addressed, that typical code provisions are complied with, and that durability and reliability standards have been met and are correctly portrayed. There, of course, may be collectors and systems of acceptable quality that have not been rated by SRCC.

A complete list of all solar collector and water-heating system manufacturers was not available, but "Suppliers" on page 32 lists the manufacturers of the SRCC-certified collectors and systems plus manufacturers who belong to the Solar Energy Industries Association. You can also check the *Thomas Register of American Manufacturers*. The Energy Information Agency's annual survey, reported in the *Renewable Energy Annual*, reports 41 active solar collector manufacturing companies shipping 7.6 million square feet of collectors in 1994. Information on SRCC-certified systems is contained in the *Directory of SRCC Certified Solar Collector and Water Heating System Ratings*. Appendices G, H, I, and J illustrate SRCC collector and system rating information. (The Florida Solar Energy Center also rates solar water-heating systems.)

Factors Contributing to the Cost-Effectiveness of Solar Water Heating

Each factor helpful, but not necessary to have all of them.

- High-cost conventional water-heating system (more than about $15 to $20 per million Btu)
- High daily volume of very-hot-water use (such as for laundries or industrial processes)
- Steady demand throughout the week and year, or highest need in the summer
- Relatively greater hot-water use during the day
- Unshaded, south-facing roof space or sunny, nearby grounds
- Good solar resource (see Figures 1, 2, 4 and 5)
- Cold-water supply (see Figure 3 and Appendix A)
- Soft water

Federal-Sector Potential

Technology Screening Process

The Federal Technology Alert (FTA) series targets technologies that appear to have significant untapped federal-sector potential and for which some federal installation experience exists. Many of the alerts are about new technologies identified through advertisements for technology suggestions in the *Commerce Business Daily* and trade journals, and through direct correspondence in response to an open technology solicitation. Those technologies are then evaluated in terms of potential energy, cost, and environmental benefits to the federal sector.

Solar water-heating is a renewable energy technology with clearly known energy, cost, and environmental benefits, and a large number of manufacturers of a variety of products—but still with substantial untapped potential for the federal sector. Solar water heating was selected for the New Technology Demonstration Program through response to the open technology solicitation.

Estimated Market Potential

The Office of Technology Assessment reported in 1991 that the U.S. Government owns or leases approximately 500,000 buildings, owns an additional 422,000 housing units for military families, and subsidizes utility bills for 9 million private households. If the objective were to reduce fossil fuel energy use and associated pollution, regardless of cost-effectiveness, the potential application of solar water heating would clearly be immense. Even limiting application to cost-effective situations, opportunities for solar water heating may still be quite substantial. Combining the large number of military and other housing units with the fact that 18% of residential energy use is for water heating and an Energy Information Administration statement that 38% of U.S. residential water heating is electric, points to a very large potential application for small systems where economics are likely to be attractive. Federal prisons, hospitals, and barracks are ideal situations for large, high-temperature systems to prove cost effective. An estimate of the number of swimming pools at federal facilities is not available, but there are certainly a significant number and the likelihood of solar pool heating being cost effective is quite good.

Application

The cost of operating conventional or backup water-heating systems is the single most important factor in determining economic feasibility for solar water-heating systems, but a variety of other factors are also important. Solar water-heating projects for federal facilities are most likely to be cost effective in three situations:

- Small, "residential-size" facilities such as visitor centers, campground showers, or staff housing, which would otherwise be dependent upon high-cost energy sources
- Large facilities that require large volumes of hot water (more than a thousand gallons per day) or have operations that use high-temperature hot water
- Swimming pools.

Where to Apply—Small Facilities

For small federal facility projects, the cost of conventional water-heating systems dominates the economic feasibility of solar water-heating systems. As can be seen from Table 1 below, the cost of conventional energy varies greatly. Note that these figures are national averages and utility rates vary greatly by region and individual facility contract. There may be regions in which the relative effective energy cost of the various energy supplies differs from that below. Table 2 shows average utility rates by region. Water heater efficiencies also vary significantly, particularly for larger heaters, from 77% to 97% for electric and from 43% to 86% for gas. You should therefore also investigate the cost-effectiveness of buying a more efficient water heater either on its own or in conjunction with installation of a solar water-heating system.

The cost of solar water-heating systems can vary widely depending upon the circumstances for a specific installation, region of the country, and other factors and are not generally available as published numbers. To get a ballpark idea, however, we can look at four residential-size systems approved by the Sacramento Municipal Utility District for its electrical-demand-reduction incentive program. The four systems are a 42-square-foot indirect thermosiphon system, an evacuated-tube integrated collector system, a 64-square-foot antifreeze system, and a 40-square-foot antifreeze system that uses a "wraparound" heat exchanger so it needs only one pump instead of two. The systems vary in cost from $2,860 to $3,180 and from meeting 61% to 74% of an assumed 57-gallon-per-day demand (averages 8.8 MBtu per year delivered energy). If we assume 20-year continuous operation and 0.5% per year operation and maintenance cost for the two passive systems and 2% per year for the two active systems, the levelized cost for the systems falls in the $20 to $23 per MBtu range. Looking at Tables 1 and 2, we can see that this is less than the average cost of electricity for federal facilities, nationally and for several of the regions, but there is little chance of competing with other types of water-heating.

As it happens, many smaller federal facilities or elements of federal facilities are located in relatively remote areas where conventional water-heating utility costs are particularly high. Three-quarters of the projects built in the 1980s under the Solar in Federal Buildings Program were small systems (less than 100 square feet of collector)

Table 1. Effective Energy Cost for Water Heating Based on National Average Federal Facility Utility Prices

	Federal Energy Cost		Average Efficiency	Effective Energy Cost
electricity	$21.05/MBtu	(7.2¢/kWh)	91%	$23.13/MBtu
propane*	$ 5.40/MBtu*	(49¢/gal)	59%	$ 9.14/MBtu
fuel oil	$ 3.85/MBtu	(53¢/gal)	56%**	$ 6.87/MBtu
natural gas	$ 3.65/MBtu	(37¢/therm)	59%	$ 6.19/MBtu

(Sources: Energy costs from General Services Administration Energy Analysis and Usage Center for Fiscal Year 1995. *Propane is 1994 refiner sales price to end users from the Energy Information Administration (Federal facility costs vary widely by individual users and averages are not tracked.) Efficiencies are from Gas Appliance Manufacturers Association April 1995 *Consumers' Directory of Certified Efficiency Ratings for Residential Heating and Water Heating Equipment*, pages 155, 193, and 195. Data are for 50-gallon first-hour rating, **except for fuel oil, which is for 100-gallon first-hour rating.

Small System Examples

Some examples of recently installed or planned small solar water-heating systems for federal facilities include a system for the Environmental Protection Agency (EPA) headquarters offices in Washington, D.C., three systems for an environmental education center in the Phoenix, Arizona, area, and three systems for a National Park Service national recreation area in Oklahoma. The 480-square-foot active, indirect system recently installed to serve the privately owned building housing the EPA headquarters will provide 71% of the demand for hot water (approximately 1150 gallons/day), saving $2,656 annually in electricity. System costs were shared by EPA and the DOE Solar Process Heat Program. With a 10% federal tax credit to the building owner, plus a rebate from the local electric utility because the system reduces peak demand, the system will pay for itself (simple payback) in 6 to 7 years.

Three small drainback systems will be part of new Bureau of Reclamation facilities in Lake Pleasant, Arizona. The Bureau is building a classroom building and two dormitories, which it will lease to the Maricopa County Outdoor Education Center (OEC). The classroom building includes a cafeteria and the dormitories will house 50 students each. The Bureau plans to use solar water-heating systems for each of the three buildings at this remote site, not only to reduce the cost of water heating but also to serve as an educational tool for students. The OEC will be an all-electric facility except for propane for auxiliary water heating. The system for the classroom building has 70 square feet of collector and 120 gallons of water storage and will meet 64% of the water-heating load. It will save 17,800 kBtu/yr. The systems for each dormitory have 145 square feet of collectors and 240 gallons of water storage. The dormitory systems will meet 45% of the annual load and each save 34,300 kBtu/yr.

A third example is currently being designed by the National Park Service for the Chickasaw National Recreation Area in Oklahoma. Three solar water-heating systems are expected to cost $35,000 and have a simple payback of 9 years. The systems will have no backup system, must be designed to shut down for winter and quickly start up in the spring, and must have very high reliability because of the remote location and the lack of operation and maintenance staff. See the case study on page 19 for a complete description and "Who Is Using the Technology" on page 24 for contacts regarding particular projects.

Table 2. Average Regional Federal Facility Utility Prices per MBtu

	Electricity	Oil	Gas
Boston	32.31	3.43	6.61
New York	33.15	3.80	4.19
Philadelphia	22.29	3.51	6.09
Atlanta	18.01	4.69	5.32
Chicago	20.36	N.A.	3.47
Kansas City	15.71	N.A.	3.36
Fort Worth	18.64	N.A.	4.29
Denver	14.02	4.14	3.83
San Francisco	28.67	N.A.	6.51
Auburn (Pacific-NW)	13.40	4.63	4.63
National Capital Region	19.08	3.61	5.04
National Average	**21.05**	**3.85**	**3.65**

(To get effective cost as per Table 1, divide electricity price by .91, fuel oil by .56, and gas by .59.)

for facilities in the National Park System. Any of the mid-temperature technologies will work well for small facilities. Solar water-heating works well for general domestic needs and for isolated facilities such as laundries, showers, visitor centers, ranger stations, and staff housing.

"Off-the-shelf" packages are often quite appropriate for small or remote facilities such as these, and a variety of SRCC-certified systems are available, so engineering design work is not necessary. If the potential system involves more than two or three collectors or will be connected to unusual plumbing, electrical, or structural systems, a bid package will likely be needed for a specific design. But in most cases, you will still be able to use off-the-shelf components and the ASHRAE *Active Solar Heating Systems Design Manual.*

In warm climates with limited freeze danger, the low-maintenance nature of passive systems is an attractive feature for isolated locations. Solar electric cells can provide power to operate solar water-heating systems if electric utility connections are unavailable. Even if grid electricity is available, solar cells are an excellent match for solar water-heating pumps and often are used as the main operation control for the system. When there is enough sunlight for the hot-water system to be operating and power is needed to run the pumps, the solar cells are also producing power.

Where to Apply—Large Systems

Although the cost of conventional energy is still the most critical factor for the economics of solar water-heating systems, for large federal facilities, it is less likely to be the factor that makes solar water-heating cost effective. Because of their size and because they are less likely to be in remote locations, most large facilities will have moderate or low-cost energy available. The cost-effectiveness of solar water-heating systems for large facilities may, however, be improved significantly by economies of scale in building a large system. While small systems with less than 100 square feet of collector generally cost between $50 and $90 per square foot of collector aperture, that figure can drop to $40 or $45 per square foot for flat-plate collector systems with more than 1000 square feet of collector, $30 per square foot for systems with more than 10,000 square feet of collector, or even $25 per square foot for parabolic-trough systems with more than 20,000 square feet of collector.

As can be seen from Table 3, that reduction in cost can make all the difference in whether a project will beat out the conventional energy costs cited above. The table divides total system cost (including 2% per year operation and maintenance) by the amount of energy the system would produce over a twenty-year lifetime. These costs do not include government acquisition costs, which tend to be relatively constant regardless of project size, giving further advantage to larger projects.

As can be seen by comparing Tables 1 and 3, none of our six sample cities can compete with conventional water-heating paying the effective national-average cost for electricity of $23.13/MBtu with small solar water-heating systems costing $75 to $90 per square foot of collector and only two at $60 per square foot. But with a larger system costing $40 or $50 per square foot, solar water-heating is quite competitive. These numbers are, of course, ballpark figures that do not take into account the specifics of particular situations, but they do illustrate the importance of either competing against expensive conventional water-heating or having a large water-heating load that allows building a large enough solar water-heating system to bring costs down.

If hot water use is more than 1000 gallons per day or conventional energy cost is more than $15 to $20 per million Btu, prospects are good for a large solar water-heating system to prove cost effective. At more than 10,000 gallons per day, parabolic-trough systems should be considered.

Nearly all prisons, hospitals, and military bases, and many other federal facilities with kitchens, laundries, or showers, use large quantities of hot water. Many of these facilities also have populations that are constant throughout the week and throughout the year and therefore have consistant water use. These factors make it worthwhile to consider a solar water-heating system—particularly if conventional energy costs are relatively high. As indicated by the case study below, additional savings are often possible during the summer by recovering heat from chiller systems. It is occasionally possible to take further advantage of economies of scale by also providing hot water for space heating or cooling or other purposes. Current thinking, however, is to look first at providing just for direct hot water use, because adding heating or cooling makes systems more complex and may adversely affect economics by increasing the variation in demand throughout the year.

Active indirect systems with flat-plate collectors work well for meeting large water-heating demands, but larger water volumes and need for high-temperature water also make high-temperature parabolic-trough or evacuated-tube systems attractive, depending on the climate. While flat-plate collector systems typically provide enough heat to efficiently raise heat-transfer fluid temperatures to as much as 160°F (70°C), the high-temperature collectors operate more efficiently when generating water or steam at much higher temperatures—up to 350°F (175°C) for evacuated-tube collectors and up to 570°F (300°C) for parabolic-trough collectors. So these systems are particularly good for facilities with high-temperature water needs such as laundries, which

Large System Examples

The Federal Bureau of Prisons recently awarded a contract to build a solar thermal system at its correctional institution in Phoenix. Similar to installations at state and local prisons, the system of parabolic-trough collectors and a thermal energy storage tank will provide hot water for inmates, laundry facilities, and kitchens. Another example of a large solar water-heating system for a federal facility is a hybrid chiller heat recovery/solar water-heating system for the Prince Kuhio Federal Building in Honolulu, Hawaii. This building has 1,083,300 square feet of floor space and houses a number of federal agencies.

The planned hybrid system combines a chiller heat recovery system with a direct solar heating system. It provides 3000 gallons of hot water per day and includes 1300 gallons of preheat water storage. The chiller heat recovery component of the system uses a compact brazed heat exchanger with a heat-transfer area of 14 square feet. The optimized solar heating component of the system has a solar array with 1361 square feet of collector area on the roof. The hybrid system allows the solar component to be about two-thirds the size it would have been without inclusion of the chiller heat recovery.

Because of the Hawaiian climate, freeze protection is not needed and the solar portion of the system circulates the potable water directly through the solar collectors without a heat exchanger. The solar component of the system provides 55% of the building's water-heating needs, with the total system providing 82% of annual demand. The system meets approximately 75% of the water-heating load in the winter and 90% in the summer. The estimated installed cost for the system is $58,389. The system offsets the need for synthetic natural gas at a cost of $1.22/therm. The project has a simple payback period of 9 years and an adjusted internal rate of return of 6.75%.

Table 3. Effective Levelized Cost per MBtu of Solar Water Heating at Selected Locations

Installed cost per square foot of collector	San Francisco, CA	Denver, CO	Chicago, IL	Washington, D.C.	Orlando, FL	Boston, MA
$30	$10.15	$ 9.69	$13.45	$13.99	$13.49	$14.91
$40	$13.54	$12.92	$17.94	$18.66	$17.98	$19.88
$50	$16.92	$16.15	$22.42	$23.32	$22.48	$24.85
$60	$20.31	$19.38	$26.91	$27.78	$26.97	$29.82
$75	$25.39	$24.23	$33.63	$34.98	$33.72	$37.29
$90	$30.46	$29.07	$40.36	$41.95	$40.46	$44.73

Calculations are based on F-chart analysis of energy savings for active flat-plate systems operating continuously for a 20-year life and 2% annual operation and maintenance cost. Operation and maintenance costs and value of energy savings are escalated at the rate of inflation (0% real) and discounted at 3%.

Andy Walker/PIX03972

Fig. 11. Solar water-heating system for indoor pool at Barnes Field House, Fort Huachuca Army Base

Swimming Pool Examples

Sandia National Laboratories has helped Camp Pendleton in Southern California refurbish an inactive solar pool heating system at one of the Camp's recreational swimming pools. The refurbishment was completed in the summer of 1995 for $10,000. The collector array has 2560 square feet of unglazed collectors using copper pipes. If the pool was used year-round, it would save $8,000 per year in natural gas. This pool is used only 3-4 months per year but was chosen as a pilot project for Camp Pendleton. The Marine Corps has six more pools with non-operating solar water-heating systems at the Camp, and these are each used year-round. Now that the pilot has been completed, the Marines are looking into refurbishing the other six systems as well.

The Barnes Field House on the Fort Huachuca Army Base in Fort Huachuca, Arizona, uses a 2000-square-foot solar system for pool heating, see Figure 11 above. The system was installed in June 1980, and supplies heat for a 3500-square-foot indoor pool. The system meets 49% of the annual load and offsets the need for 835 MBtu of natural gas per year.

A noteworthy example of local government use of solar water-heating is the city of Santa Clara, California, solar pool heating program. Since 1975, the city's municipal utility has been providing for the design, installation, and on-going maintenance of solar pool heating systems. The pool owner pays an initial installation fee to cover the value of the labor and permanent materials required to install a solar heating system. The recoverable components, including the panels and automatic controls, are rented; the monthly fees are set by the city council as a "Solar Utility Rate." Each user and the city enter into a contract that defines the responsibilities of each party and sets the monthly utility fee proportional to the size of the solar energy system. Fees are designed to repay installation costs as though repaying an amortized loan for a term equal to the expected life of the equipment. To date, more than 300 of the 800 pools in the city are heated by the city's solar program.

typically use water as hot as 180°F (82°C); kitchens, which typically use water temperatures from 140°F to 195°F (60°C to 91°C) for dishwashing; or industrial processes.

Where to Apply— Swimming Pools

One of the most consistently cost-effective uses for solar water-heating systems is for heating swimming pools. Low-temperature collectors—most of which are for swimming pools—have accounted for the majority of solar water-heating systems sold since 1991 (more than 85% on a square-foot basis in 1993). Many military bases and other federal facilities have swimming pools, so there may be many cost-effective opportunities for installation of solar swimming pool heaters. If you have a pool and it is now heated, you may reap great savings, because solar pool-heating systems frequently pay for themselves within two to four years—even when replacing natural gas heat. If your pool is not now heated, you may be able to extend your season by several months. If you are faced with budget cuts, energy savings may allow you to keep a pool open.

The pool's filter system pumps the water through the collector and the heat storage is in the pool itself. Because only a modest temperature increase is needed, most systems use inexpensive, unglazed low-temperature collectors, which are often essentially systems of water tubes built into dark plastic. "Off the shelf" packages are generally appropriate and maintenance is minimal. Some smaller systems are operated manually or with timers, but larger systems are operated by electronic sensors and controls. When the collector temperature is sufficiently greater than the pool temperature, a diverting valve—the only moving part—diverts water from the filter system through the collector loop. As with other hot-water uses, conservation of generated heat is generally the most cost-effective investment and swimming pool covers should be considered at the same time as a solar water-heating system.

Brochures on covers and solar water-heating systems for swimming pools and a software package that can evaluate the economic feasibility for your pool are available from the Energy Efficiency and Renewable Energy Clearinghouse. Call 1-800-DOE-EREC and ask for the "Energy Smart Pools" package.

Application Screening

The first step toward installing a solar water-heating system is to assess your hot-water needs. How much hot water at what temperature do your various facilities use (or are new facilities expected to use), on what kind of schedule? How much do you pay for the energy to heat that water? Can you save money with a more efficient conventional water heater? What options do you have for reducing hot-water use or lowering the temperature of water provided?

The next step is to obtain a preliminary estimate of whether solar water-heating will be cost effective. The FEMP Federal Renewables Program at the National Renewable Energy Laboratory has developed a computer program known as Federal Renewable Energy Screening Assistant (FREScA) that can make such a preliminary assessment for you. See the "How Do You Figure" sidebar on page 17 for a list of the necessary information. (For swimming pools, you can use "Energy Smart Pools" software instead of FREScA.)

For smaller projects, a clearly positive FREScA calculation will often be sufficient to proceed to system purchase. For large systems, a positive FREScA assessment should be followed up with a formal feasibility study (see "Economic Criteria" below). Larger projects will likely require a private engineer at some point, but the FEMP Federal Renewables Program staff can provide fairly extensive assistance.

A general rule of thumb for federal facilities is that a renewable energy installation should pay for itself within about 10 to 15 years. Because the lifetime of a system can be as much as 30 years, that means you can look forward to as much as 20 years of "free energy."

The Right Collector for the Right Use

Solar collector efficiency is a function of optical gain[1] minus heat loss[2]. Collectors for low-temperature applications (like swimming pools) have high optical gains (no cover glass and high surface absorptivity) but they also have high heat loss because they are uninsulated. Mid-temperature collectors, for domestic water heating, have cover glass and insulation to reduce heat loss, but the cover glass results in slightly lower optical gains due to reflection of sunlight off the glass. High-temperature collectors such as evacuated tubes and focusing parabolic troughs also have optical losses from cover glass and focusing reflectors, but they retain heat at very high temperatures, making them ideal for high-temperature applications like absorption cooling and power generation.

The type of collector best suited to a particular application depends both on the temperature above ambient to which the water is to be heated and on collector cost. The following table of energy generation per area of collector (based on selected collectors from the SRCC Directory) shows that low-temperature collectors are indeed the most effective for low-temperature applications; mid-temperature collectors are the best for medium-temperature applications; and high-temperature collectors are the best for high-temperature applications. For low-temperature applications the more expensive insulated collectors offer no advantage, but at high temperatures they are essential to collect solar heat.

	Unglazed Pool Heater (low)	**Glazed Collector (mid)**	**Evacuated-Tube Collector (high)**
Optical Gain Coefficient[1]	.87	.74	.50
Heat Loss Coefficient[2]	21.3 W/M²°C (3.7 Btu/hr ft²°F)	4.9 W/M²°C (.9 Btu/hr ft²°F)	21.3 W/M²°C (3.7 Btu/h rft²°F)
Amount Temperature of Water Entering the Collector Exceeds Ambient	**Clear Day (6.4 kWh/m²day-2000 Btu/ft²day) Heat Delivery**		
5°C (9°F) (low)	4.1 kWh/m²day (1300 Btu/ft²day)	4.0 kWh/m²day (1250 Btu/ft²day)	3.0 kWh/m²day (1000 Btu/ft²day)
20°C (36°F) (medium)	1.5 kWh/m²day (470 Btu/ft²day)	3.2 kWh/m²day (1000 Btu/ft²day)	2.8 kWh/m²day (900 Btu/ft²day)
50°C (90°F) (high)	0 kWh/m²day (0 Btu/ft²day)	2.0 kWh/m²day (640 Btu/ft²day)	2.4 kWh/m²day (770 Btu/ft²day)

[1] fraction of sunlight captured as heat

[2] mulitiplier for the amount that the temperature of the return water that enters the collector exceeds outside air temperature, to determine heat loss from the collector. For example, the heat collected by a glazed collector heating water from 60°C when it is 0°C outside and the sun is shining at 1000 W/m², would be: $.74 (1000\ W/m^2) - 4.9\ W/m^2\ °C\ (60°C - 0°C) = 446\ W/m^2$.

System Selection and Procurement

As a general rule, the optimal type of solar water-heating system depends on the increase in water temperature that the system will be used for. Low-temperature systems—with no cover glazing or insulation—absorb a high percentage of the available solar heat but also lose sizable amounts of energy. They are therefore best for uses such as swimming pools that only require a modest increase in water temperature. Adding glazing and insulation cuts down on heat absorption but greatly increases heat retention, so the added cost of mid-temperature systems is cost effective for most applications requiring greater increases in water temperature. High-temperature systems, such as evacuated tubes with their very high insulation and

Table 4. Solar Water Heating System Characteristics: Factors Useful in Selecting System Type for Particular Situation

		Suitable system size	Cost/ ft² for 40 ft² unless noted	Freeze tolerance	Hard-water tolerance	Maintenance need
Low-Temperature Systems						
Unglazed		for pools	\$10-\$25 (400 ft²)	none	good	very low
Passive Mid-Temperature Systems						
Integrated collector		small	\$50-\$75	moderate	minimal	very low
Thermo-siphon	direct	small	\$40-\$75	none	minimal	low
	indirect	small	\$50-\$80	moderate	good	low
Indirect, Active, Mid-Temperature Systems						
Flat-plate, antifreeze		small or large	\$50-\$90 / \$30-\$50 (30,000 ft²)	excellent	good	high
Flat-plate, drain-back		small	\$50-\$90	good	good	high
Direct, Active, Mid-Temperature Systems						
Drain down		small		corrections being	minimal	high
Recirculating		small		developed	minimal	high
High-Temperature Systems						
Evacuated tube	direct	small	\$75-\$150	good	minimal	high
	indirect	large	\$75-\$150	excellent	good	high
Parabolic trough		large	\$20-\$40 (30,000 ft²)	excellent	good	high

parabolic troughs with their concentration of the sunlight, are most effective when used to provide either very large amounts of hot water or high temperature uses such as kitchens, laundries, or industrial uses. (See sidebar on page 15 for detailed discussion.) Table 4 summarizes characteristics that may make certain system types particularly suitable or inappropriate for your facility.

Having found that a solar water-heating system is likely to be cost effective for your facility, chosen one or two appropriate system types, and determined the approximate size of the system, you can now probably pick out the most appropriate products from the SRCC *Directory* (for smaller systems) and proceed toward purchase in accordance with Federal Acquisition Regulations. For most agencies this means small purchase agreements based on a request for quotes for projects costing less than \$25,000, requests for quotes including notice in the *Commerce Business Daily* for projects costing from \$25,000 to \$50,000, and going out for bids for anything more than \$50,000. (A new electronic mail advertising system in the works will allow requests for quotes to be used for anything up to \$100,000.)

For smaller systems, specifics on your hot-water usage pattern, water supply temperature, and detailed utility rate schedule will probably be sufficient additional data for potential vendors to supply the cost, performance, and other information you need to select a system and to decide whether to proceed. It is not quite like going to the discount store for a conventional home water heater, but complete off-the-shelf systems are available. FEMP is working on getting solar water-heating systems on the GSA purchase schedule (perhaps by 1997, check with the FEMP Help Line), which will make it easier to obtain specific models at fixed prices. They are also developing product recommendations for solar water-heating systems. In the meantime, certified systems from the SRCC Directory are a place to start, and there may be many other good systems to choose from.

For larger systems, you will need engineering help to select an optimum system and do a detailed economic assessment for that system (See "Economic Criteria" below). You may have to go out for bids to hire an engineer to design the system, but can probably do so with a sole-source contract for professional services. The designer cannot then be a vendor for the system but can write the specifications for the bid request and either install or supervise the system's installation. Appendix E is an example of specifications used for the Chickasaw National Recreation Area case study. Check with the FEMP Federal Renewables Program (303-384-7509) for other previously prepared specifications that may be more similar to your planned system.

Economic Criteria

The policy for evaluating whether solar water-heating or other renewable energy projects are cost effective and therefore appropriate for federal facilities is contained in 10 CFR Part 436A of the *Code of Federal Regulations*. The principal criterion of these regulations is that the life-cycle cost (value in base-year dollars of all costs for the full analysis period) for the project must be less than any alternatives, including projected utility payments with the existing water-heating system. (Three similar criteria may be used instead for retrofit projects, and projects with "insignificant" cost are presumed cost effective.)

Executive Order 12902 goes beyond the cost-effectiveness regulations to stipulate that if a project will pay for itself (simple payback period time for savings to return the cost of the investment) in less than 10 years, it shall be built (Sections 103 and 303). For most situations the 10-year payback criterion will be more rigorous than the life-cycle-cost criterion. Many projects will meet the life-cycle-cost criterion even though their simple payback is somewhat longer than 10 years. Agencies must build projects with a simple payback of less than 10 years, but may also build any project that meets the life-cycle-cost criterion.

Life-cycle-cost analysis calculates the sum during the life of the project of the present value of investment costs, operation and maintenance, replacement costs, and energy costs, minus salvage value of replaced parts. A manual for life-cycle costing (National Institute of Standards and Technology [NIST] Handbook 135), an annual set of prescribed energy prices and discount rates (NISTIR 85-3273), and Building Life-Cycle Cost (BLCC) software (NIST 4481) are all available by calling the FEMP Help Line at 800-DOE-EREC. (Some agencies allow simpler life-cycle calculations, but the BLCC is required if FEMP funding is involved. You may also need *Mean's Mechanical Cost Data* [available from 800-448-8182] for estimating system component costs.)

In addition to determining whether a project is cost effective, economic analysis helps to determine the size of the solar water-heating project that will minimize costs during the life of the project. The cost of conventional water-heating options will usually be the biggest factor in determining optimal project size. The higher the conventional water-heating cost, the larger portion of the load you are likely to be able to meet effectively with a solar water-heating system. Calculating the resulting savings in conventional water-heating (subtracting any operation and maintenance cost for the system) and using an appropriate discount rate or interest factor to compare present system cost to future savings determines whether the system is a worthwhile investment. The prescribed discount rate for evaluating renewable energy projects for federal facilities for 1995 is 3%. A low discount rate such as this favors future savings over initial investment—and thus encourages renewable energy projects such as solar water-heating systems.

Although standard life-cycle-cost analysis does not include a way to take credit for environmental externalities such as benefits of reducing fossil fuel consumption, these may be an important consideration if the economic efficiency calculation is close. The National Park Service has developed guidelines for calculating and including avoided air emissions resulting from reduced electrical power production in their internal economic evaluation of large energy efficiency and renewable energy projects (Doug DeNio, 303-969-2162). Some agencies have chosen to relax the economic evaluation criteria somewhat for showcase buildings in new facilities or demonstration projects at existing facilities. Projects must be basically cost effective, however, or else they do not make good demonstrations.

How Do You Figure?

To obtain a preliminary analysis of whether solar water-heating would be cost effective for your situation, use the Federal Renewable Energy Screening Assistant (FREScA) software package, available from the Federal Renewables Program at the National Renewable Energy Laboratory (NREL): 303-384-7531. Federal Renewables Program staff can also do the analysis for you, if you provide the following data:

- Hot-water use in gallons per day
- Fuel type and cost
- Zip code
- Incoming cold-water temperature
- Outgoing hot-water-supply temperature
- Area of southern exposure roof or nearby grounds available for system
- Tilt and direction of roof area.

To obtain comprehensive solar resource data (the FREScA system does include solar resource data based on your zip code), request the NREL *Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors* (see Appendix B) or the CD-ROM of the National Solar Radiation Data Base.

To estimate hot-water use, check your hot-water use records; install a meter and track usage; or project demand based on average use for various facilities as found in the American Society of Heating, Refrigeration and Air-Conditioning Engineers' *Handbook of Applications*. Typical usage per day per occupant in gallons is 20-30 for housing, 30 for hospitals, 5 for dining facilities, and 3 for other uses.

To determine incoming water temperature (may vary considerably with season), call your water utility, check the supply with a thermometer, or refer to Figure 3 and Appendix A. In some instances, the average annual air temperature also serves as a rough indication of water supply temperature.

To calculate system output information more rigorously than the preliminary analysis provided by FREScA, use a computer tool such as F-chart, or consult with Federal Renewables Program staff or a solar water-heating system supplier.

The optimum size for collector and storage will depend upon fuel cost, your hot water use pattern, and the cost of the system being considered, but expect storage to roughly match one day's use and collector size to be approximately 1.0 square feet per gallon of storage. (The resulting system should meet as much as about two-thirds of annual demand.) Precise optimization of system size will require both a calculation of output and an evaluation of the economics of contemplated systems.

To evaluate the economics of a contemplated system in detail, use the FEMP *Life-Cycle Costing Handbook* and associated BLCC software (call the FEMP Help Line at 800-DOE-EREC), or consult with the FEMP Federal Renewables Program or a private engineer.

To evaluate the economic feasibility of covers and solar water-heating systems for your swimming pool, use Energy Smart Pools software, also available from the FEMP Help Line.

Funding Sources

The first place to look for funding is regular internal agency funding: local purchasing authority for very small projects; Congressionally approved line items for very large projects; and regular agency funding. Special agency-specific funds, such as the Defense Department's Energy Conservation Investment Program, may be available for energy efficiency and renewable energy projects. Although there is not expected to be any funding available for fiscal year 1996, the Federal Energy Efficiency Fund of the U.S. Department of Energy (DOE) and other programs have provided funding assistance for renewable energy projects at federal facilities in the past. Call the FEMP Federal Renewables Program (303-384-7509) for the current status of any available funding.

An important new financing option available to federal facilities is energy savings performance contracting (ESPC). A private energy services contractor designs and installs the system, paying the full cost of parts and labor, or the project can be financed by a third party. The federal facility pays nothing up front beyond initial feasibility studies. The contractor is responsible for operating and maintaining the system and training facility personnel in its use. The facility then pays the contractor for the energy received as a discounted percentage (usually about 15% less) of what it would have cost from the utility. The facility pays these "utility savings" bills for a specified contract period (up to 25 years) from its utility or operation and maintenance budget, after which the facility retains the savings and equipment. Thus, the contractor and the facility share the savings in utility costs. (There are now quite a few companies set up to do energy service contracts; an association is listed on page 24.) The facility must announce intent to consider ESPC proposals in the *Commerce Business Daily,* but may accept unsolicited proposals. The DOE has a list of prequalified energy service companies and model procurement documents, as well as a manual on the ESPC program (for copies, call the FEMP Help Line at 800-DOE-EREC).

Through 1995, 17 performance contracts at a total cost of approximately $30 million have been awarded under the ESPC program (mostly energy efficiency so far, but solar water-heating is clearly eligible). Both the contractors and FEMP are developing a track record and experience base that will help make projects go more smoothly. FEMP is currently working on setting up indefinite quantity contracts to allow qualified contractors to serve any eligible federal facility project within a region.

The obvious advantages of performance contracting are limited initial investment, no capital investment, no operation and maintenance responsibility, and no technical or financial risk for the success of the project. ESPC contracting is especially attractive for very large projects that require substantial capital outlay or extensive operation and maintenance. However, if funds can be obtained to build a project, straight agency funding brings the full cost savings back to the facility for the life of the project. Also, even with prequalified contractors, the paperwork necessary for performance contracting is significant enough to make it unattractive for smaller projects for which construction can be more easily funded.

More than half the states and many local governments do provide incentives for solar thermal collector or solar cell system purchases. These programs are not generally directly applicable to federal facilities, but may be helpful in certain situations.

Utility company incentives for demand reduction and load management are currently an important nonfederal source of financial assistance for solar water-heating systems. Demand-side-management activities, such as promoting solar water-heating systems, can save a utility from investing in system expansions or help them comply with air quality programs. Among the utilities that have been actively providing rebates or other financial incentives for new solar water-heating systems are the Sacramento Municipal Utility District, Florida Power and Light, and the Eugene Water and Electric Board. Wisconsin Public Service and the Hawaiian Electric Company are developing programs.

Although most programs such as these were designed for residential customers, they also generally apply to commercial facilities including federal buildings. Federal facilities may be able to negotiate specific incentives for larger projects beyond the scope of standard programs or where standard programs do not exist. On the one hand, anticipated utility industry restructuring may cut back on demand-side-management programs, but on the other, it may encourage utilities to spin off energy service companies specifically set up to design and install energy efficiency and renewable energy projects.

Technology Performance

An estimated one million residential and 200,000 commercial solar water-heating systems have been installed in the United States. 718 systems were installed at federal facilities during or shortly after 1981 through the Solar in Federal Buildings Program. For discussion of experiences with recent installations, see the sidebars on small system, large system, and swimming pool examples on pages 11, 12, 13, and 14 and "Who Is Using the Technology" on page 24. The technology is well developed and today's solar water-heating systems are well proven and reliable when correctly matched to climate and load. The current market consists of a relatively small number of manufacturers and installers that provide reliable equipment and quality system design. A quality assurance and performance rating program, instituted by a voluntary association of the solar industry and various consumer groups, makes it easier to select reliable equipment with confidence.

Solar water-heating is a renewable energy technology that saves nearly as much (there is usually some excess capacity) conventional energy use as it produces. Water heating accounts for about 18% of energy use in residential and 4% of energy use in commercial buildings. Solar water-heating can be used to replace much of that electrical and fossil fuel energy consumption, wherever it is found cost effective. Cost-effective system design often matches hot-water use in the summer and partially meets the demand in winter for a net production of about two-thirds of total hot-water use.

System Maintenance

Solar water-heating systems are long-lived and require relatively little attention. But, as with any mechanical system, some basic maintenance is essential to keep the system functioning smoothly. All solar water-heating systems should be checked out at least twice per year. Proper operation of sensors and controllers should be tested for active systems. A primary cause of problems is calcium carbonate deposits (scaling) from hard water. Other major maintenance concerns are pumps failing and tanks developing leaks. As with conventional water heaters, pressurized hot-water tanks will have about a 15-year lifetime. Ten-year warranties on collectors are the industry standard.

Integrated collector and thermosiphon systems need little maintenance. Relief valves ($10) will require replacement approximately every 15 years, as with any hot-water system. Unless you have hard water, the systems should not require flushing and should last 20 to 30 years. Direct thermosiphon systems are not recommended for facilities with hard water. For integrated collector and indirect thermosiphon systems, very hard water necessitates additional maintenance and your contractor may suggest flushing or other measures. The antifreeze in indirect thermosiphon systems should be replaced every 5-10 years.

Direct active systems such as drain-down and recirculating systems are also strongly affected by scaling and are not generally recommended where water is hard. One way to combat scaling problems is to install an extra anode rod in the water heater. (All conventional water heaters have anodes and replacing them could extend service life, but they are often hard to get at.) In addition, controllers and valves of direct active systems must be very carefully maintained to prevent freezing problems.

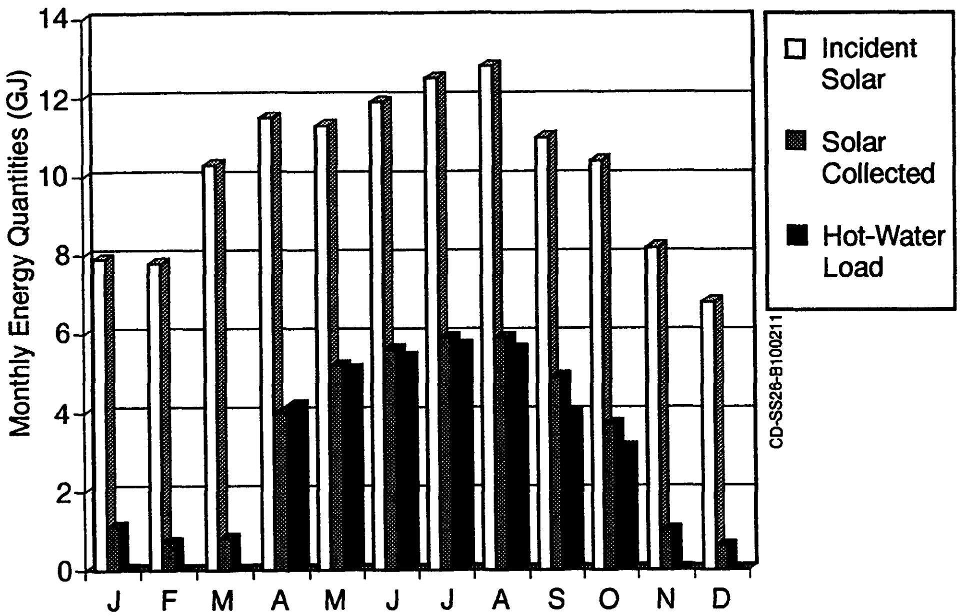


Fig. 12. Monthly Energy Analysis—Small Comfort Station, Chickasaw National Recreation Area

Because drain-back systems are indirect and can use demineralized water for the heat-transfer loop, scaling from hard water is not as serious. Only the potable-water side of the heat exchanger requires cleaning. (It should be checked every year or so until you have a sense of the scaling problem for your water supply.) If the system is not pressurized, it may require regular replacement of evaporated water or checking the valve that does that. Sensors, controllers, and pumps should be checked regularly. Pumps ($50 to $200) can be expected to wear out after 10 to 20 years, as in any hot-water system. Modern controllers ($100 to $200) have a mean lifetime of at least 20 years.

As with drain-back systems, antifreeze systems are subject to scaling only on the potable-water side, but require maintenance and occasional replacement of tanks, pumps, and electronics. Antifreeze systems also require replacement of the propylene glycol (because of breakdown of corrosion inhibitors) every 5 to 10 years or more often if the system has excess capacity and frequently maintains a high temperature.

Unglazed, low-temperature systems must be drained when the pool is closed for the winter and when freezing temperatures are expected. The collectors should last from 15-20 years. Vacuum relief valves and pressure relief valves ($10 each) will require replacement every 5-15 and 10-20 years, respectively.

Because parabolic-trough systems involve very-high-temperature and -pressure fluid, they should be closely monitored. Operation and maintenance is generally included as part of the contract for design and installation of parabolic-trough systems. The mirror surfaces should be washed every few months and will require replacement after about 15 years. Seals on the pumps should be replaced every 10 years or so and the controls for the tracking equipment may need replacing after anywhere from 10 to 30 years. But the large pumps used for trough systems and the tracking equipment should last for the life of the project.

Case Study — Chickasaw National Recreation Area

The Chickasaw National Recreation Area is located approximately 100 miles south of Oklahoma City, Oklahoma. The National Park Service is planning solar water-heating for one large and two small comfort stations. They anticipate primarily summer use for all three buildings with very little winter use. For the months of April through October,

Table 5. Characteristics of the Solar Water Heating Systems Proposed for Chickasaw National Recreation Area

Characteristic	Small Comfort Stations	Large Comfort Station
Daily hot-water use	660 gal/day	1500 gal/day
Temperature	at least 95°F (35°C)	at least 105°F (41°C)
Collector area	194 s.f.	484 s.f.
Storage volume	500 gal	1000 gal
Load met by solar	9,394 kWh	18,194 kWh
Hours water temperature is less than target	345 hrs/year (95°F)	579 hrs/year (105°F)
System efficiency	45%	34%
Solar system cost	$7,804 ($40/s.f.)	$16,100 ($33/s.f.)
Net present value	$16,650	$32,248
Internal rate of return	6.2%	5.9%
Simple payback period	9 years	9 years
Discounted payback period	10 years	11 years
Savings-to-investment ratio	2.1	2.0

the average hot-water load for each of the small comfort stations is projected to be 660 gallons per day at a minimum temperature of 95°F (35°C); for the large comfort station it is projected to be 1500 gallons per day at a minimum of 105°F (41°C). There will be no backup water-heating, so an important system design criterion was how many hours during the use season the system would not be able to meet these minimum temperatures.

The solar water-heating systems for each of the small comfort stations will consist of 194 square feet of collector area on the roof and 500 gallons of preheat water storage in the mechanical room. Each of these systems is expected to provide 32 MBtu (9394 kWh) of heat energy annually—the total hot-water supply. Hourly simulations estimate that the delivered water temperature will be less than the desired temperature of 95°F for 345 hours during the use season. The efficiency of the system in converting solar radiation to heated water is estimated at 45% averaged over the use season. Figure 12 shows solar energy incident on the array, energy collected by the array, and annual total hot-water load for all 12 months for a small comfort station. The estimated installed cost for each system is $7,804. A cost breakdown is included in Table 5. The calculated rate of return is 6.2% and the simple payback period is 9 years. The life-cycle-cost estimate for the project developed using the BLCC software is shown in Appendix D.

The solar water-heating system for the large comfort station will consist of 482 square feet of collector area on the roof and 1000 gallons of preheat water storage in the mechanical room. The estimated installed cost for the system is $16,100. This system meets the use season load with the exception of 579 hours. The rate of return is 5.9% and the simple payback period is 9 years. A summary of the characteristics of both systems is shown in Table 5.

A drain-back system is recommended for this application. Other system types were considered but rejected for this particular application for the following reasons:

- The high stagnation temperatures anticipated in wintertime would be damaging to the fluids in an antifreeze system.
- Drain-down systems and recirculation systems both circulate potable water through the collectors. The hard well water used at this site would contribute to early obstruction of the small collector flow passages with mineral deposits.
- Direct thermosiphon systems offer no freeze protection and indirect thermosiphon systems offer no stagnation protection.
- Site considerations rule out ground-mounted tracking parabolic-trough systems.

Aesthetics of the site are a primary consideration. Thus, only the south-sloping roofs of the buildings were considered for siting solar arrays. The shading effects of surrounding hills, trees, and buildings are not of great concern because the solar heating system collects energy mostly in the middle of the day and in summer, when the sun is overhead.

The Technology in Perspective

Despite problems with some 1980s installations, solar water-heating is a proven technology that can play a significant role in reducing conventional energy use at federal facilities throughout the country. There are a variety of different types of solar water-heating systems available to match the needs of different situations. Facilities dependent on high-cost water heating are quite likely to find solar water-heating systems economically attractive. Use for swimming pool heating is generally economical regardless of conventional water-heating cost. Many facilities with large, constant water use loads (prisons, hospitals and military barracks are frequently good candidates) will find that large solar water-heating systems can be designed to economically meet their needs. Even where the economic payoff is small, such projects are of great value because of the added benefits of reducing pollution and climate-change emissions by reducing fossil-fuel combustion. (Federal facilities also need to comply with Executive Order 12902 and can play a valuable role by setting good renewable energy use examples.)

The FEMP Federal Renewables Program at the National Renewable Energy Laboratory can quickly assess whether solar water-heating is likely to be economically attractive for a federal facility with a minimal amount of information. Financial assistance beyond regular agency funding will likely be very limited at least for the near future, but through the Energy Savings Performance Contracting program of the Federal Energy Management Program, agencies have the option of avoiding all installation costs and paying for solar water-heating systems via utility savings bills.

The outlook for solar water-heating at federal facilities is excellent from standpoints of technological feasibility, compatibility with existing facilities, conventional energy use reduction, and pollution and climate-change gas emission reduction. Solar water heating can be effectively used at any facility that wants to make a commitment to using it. For swimming pool heating, when competing against expensive water heating, and where hot-water use is very large and consistent, there is a good possibility of solar water heating being found economically attractive. Technological breakthroughs to dramatically reduce costs and make solar water heating economically attractive for other situations do not appear imminent. Nonetheless, the situations where solar water heating has good likelihood of being cost effective are substantial enough that the as-yet-untapped potential for application at federal facilities is still quite significant.

Suppliers

Manufacturers of Collectors and Distributors of Systems Certified by the Solar Rating and Certification Corporation:

American Solar Network, Ltd.
5840 Gibbons Dr.
Carmichael, CA 95608
(916) 481-7200
(916) 487-7225 Fax

Heliodyne, Inc.
4910 Seaport Ave.
Richmond, CA 94804
(510) 237-9614
(510) 237-7018 Fax

Nippon Electric Glass America, Inc.
626 Wilshire Blvd., Suite 711
Los Angeles, CA 90017
(213) 614-8667
(213) 623-2041 Fax

Radco Products, Inc.
2877 Industrial Parkway
Santa Maria, CA 93455
(805) 928-1881
(805) 928-5587 Fax

SOLMAX
3951 Development Dr., #11
Sacramento, CA 95838
(916) 924-1040
(916) 924-1098 Fax

SunEarth, Inc.
4315 S. Santa Ana Street
Ontario, CA 91761
(909) 984-8737
(909) 988-0477 Fax

Thermo-Dynamics, Ltd.
81 Thornhill Dr.
Dartmouth, Nova Scotia
Canada B3B 1R9
(902) 468-1001
(902) 468-1002 Fax

Collector Manufacture Only:

American Energy Technologies
P.O. Box 1865
Green Cove Springs, FL 32043
(904) 284-0552
(904) 284-0006 Fax

Heliocol USA, Inc.
927 Fern St., Suite 200
Altamonte Springs, FL 32701
(407) 831-1941
(407) 831-1208 Fax

Sunsiaray Solar Mfg., Inc.
7095 Schoolcraft
Davison, MI 48423
(810) 653-3502
(810) 744-4322 Fax

Sun Trapper Solar
12118 Radium St.
San Antonio, TX 78216
(512) 341-2001
(512) 341-2652 Fax

System Distribution Only:

Heliotrope General, Inc.
3733 Kerora Dr.
Spring Valley, CA 91977
(800) 552-8838
(619) 460-9211 Fax

Morley Manufacturing, Inc.
P.O. Box 1540
Cedar Ridge, CA 95924
(916) 477-6527
(916) 477-0194 Fax

Solahart
155 Mata Way, Suite 109
San Marcos, CA 92069
(800) 233-7652
(619) 736-7023 Fax

Sun, Wind & Fire Co.
7637 S.W. 33rd Ave.
Portland, OR 97219
(800) 397-9651
(503) 245-0414 Fax

Solar Energy Industries Association (SEIA) Membership — Active Hot Water Systems:

American Energy Technologies, Inc.	Green Cove Springs, FL	(904) 284-0552
American Solar Network, Ltd.	Carmichael, CA	(916) 481-7200
BSAR Solar	Solano Beach, CA	(619) 259-8864
Bio-Energy Corporation	Kingston, NY	(914) 336-7700
Capitol Solar Service Company	Castle Rock, CO	(303) 792-0155
Heliodyne, Inc.	Richmond, CA	(510) 237-9614
Industrial Solar Technology Corp.	Golden, CO	(303) 279-8108
Metro Solar, Inc.	Denver, CO	(303) 782-9099
Morley Manufacturing	Cedar Ridge, CA	(916) 477-6527
Radco Products, Inc.	Santa Maria, CA	(805) 928-1881
Solar Development, Inc.	Riviera Beach, FL	(407) 842-8935
Sun Trapper Solar Systems, Inc.	San Antonio, TX	(210) 341-2001
SunEarth, Inc.	Ontario, CA	(909) 984-8737
SunSolar	Bohemia, NY	(516) 563-4900
Sunquest	Newton, NC	(704) 465-6805
Sunshine Plus	West Babylon, NY	(516) 789-9360
Techno-Solis Inc.	Clearwater, FL	(813) 573-2881
Thermal Conversion Technology	Sarasota, FL	(813) 953-2177

SEIA Membership — Integrated Collector and Thermosiphon Systems

American Energy Technologies, Inc.	Green Cove Springs, FL	(904) 284-0552
Edwards Energy Systems	Perth, Australia	(619) 455-1999
Hardie Energy Products Pty, Ltd/Solahart	San Marcos, CA	(800) 233-7652
Mercury Solar	Honolulu, HI	(808) 373-2257
Radco Products, Inc.	Santa Maria, CA	(805) 928-1881
Solahart America	San Marcos, CA	(800) 233-7652
SunEarth, Inc.	Ontario, CA	(909) 984-8737
Sunshine Plus	West Babylon, NY	(516) 789-9360
Thermal Conversion Technology	Sarasota, FL	(813) 953-2177

SEIA Membership — Evacuated-Tube Systems

FAFCO, Incorporated	Redwood City, CA	(415) 363-2690
Mercury Solar	Honolulu, HI	(808) 373-2257
SunSolar	Bohemia, NY	(516) 563-4900
Sunshine Plus	West Babylon, NY	(516) 789-9360
Thermomax USA, Ltd.	Columbia, MD	(410) 997-0778

SEIA Membership — Trough Systems

Energy Concepts Company	Annapolis, MD	(410) 266-6521
Industrial Solar Technology Corp.	Golden, CO	(303) 279-8108
Solar Kinetics/SOLOX	Dallas, TX	(214) 556-2376

SEIA Membership — Swimming Pool Heating Systems

Aquatherm Industries, Inc.	Lakewood, NJ	(908) 905-9002
Art of Solar, The	Rancho Cucamonga, CA	(909) 483-2495
Bio-Energy Corporation	Kingston, NY	(914) 336-7700
Capitol Solar Service Company	Castle Rock, CO	(303) 792-0155
FAFCO, Incorporated	Redwood City, CA	(415) 363-2690
Harter Industries, Inc.	Holmdel, NJ	(908) 566-7055
Heliocol USA Inc.	Altamonte Springs, FL	(407) 831-1941
Heliodyne, Inc.	Richmond, CA	(510) 237-9614
Industrial Solar Technology Corp.	Golden, CO	(303) 279-8108
Metro Solar, Inc.	Denver, CO	(303) 782-9099
Morley Manufacturing	Cedar Ridge, CA	(916) 477-6527
Radco Products, Inc.	Santa Maria, CA	(805) 928-1881
Sealed Air Corporation	Hayward, CA	(800) 451-6620
Solahart America	San Marcos, CA	(800) 233-7652
Sun Trapper Solar Systems, Inc.	San Antonio, TX	(210) 341-2001
SunEarth, Inc.	Ontario, CA	(909) 984-8737
SunSolar	Bohemia, NY	(516) 563-4900
Sunquest	Newton, NC	(704) 465-6805
Sunshine Plus	West Babylon, NY	(516) 789-9360
Techno-Solis Inc.	Clearwater, FL	(813) 573-2881

SEIA Membership — Liquid Collectors

American Solar Network, Ltd.	Carmichael, CA	(916) 481-7200
Bio-Energy Corporation	Kingston, NY	(914) 336-7700
Heliodyne, Inc.	Richmond, CA	(510) 237-9614
Mercury Solar	Honolulu, HI	(808) 373-2257
North Star Company	Gardena, CA	(310) 515-2200
Radco Products, Inc.	Santa Maria, CA	(805) 928-1881
Solar Development, Inc.	Riviera Beach, FL	(407) 842-8935
Sun Trapper Solar Systems, Inc.	San Antonio, TX	(210) 341-2001
SunSolar	Bohemia, NY	(516) 563-4900
Sunquest	Newton, NC	(704) 465-6805
Sunshine Plus	West Babylon, NY	(516) 789-9360
Techno-Solis Inc.	Clearwater, FL	(813) 573-2881
Thermal Conversion Technology	Sarasota, FL	(813) 953-2177

SEIA Membership — Tanks and Thermal Storage

Capitol Solar Service Company	Castle Rock, CO	(303) 792-0155
Heliodyne, Inc.	Richmond, CA	(510) 237-9614
Mercury Solar	Honolulu, HI	(808) 373-2257
Metro Solar, Inc.	Denver, CO	(303) 782-9099
Morley Manufacturing	Cedar Ridge, CA	(916) 477-6527
Solar Development, Inc.	Riviera Beach, FL	(407) 842-8935
Sun Trapper Solar Systems, Inc.	San Antonio, TX	(210) 341-2001
SunEarth, Inc.	Ontario, CA	(909) 984-8737
SunSolar	Bohemia, NY	(516) 563-4900
Sunquest	Newton, NC	(704) 465-6805
Sunshine Plus	West Babylon, NY	(516) 789-9360

Who Is Using the Technology

Bureau of Reclamation — Outdoor Education Center, Lake Pleasant, Arizona
— George Newland 303-236-9100

Environmental Protection Agency — Headquarters Building in Washington, D.C.
— Phil Wirdzek 202-260-2094

General Services Administration — Prince Kuhio Federal Building, Honolulu, Hawaii
— Richard Buziak 808-541-1951

National Park Service — Chickasaw National Recreation Area, Oklahoma
— Mark Golnar 303-969-2327

National Park Service — El Portal Employee Housing, Yosemite National Park
— Andy Roberts 303-969-2566

United States Army — Swimming pool, Fort Huachuca, Arizona
— Bill Stein 520-533-1861

United States Marine Corps — Swimming pool, Camp Pendleton, California
— Major Dick Walsh 703-696-1859

For Further Information

Organizations

Federal Energy Management Program (FEMP)
Help Line: 800-DOE-EREC

FEMP Federal Renewables Program (at the National Renewable Energy Laboratory)
1617 Cole Blvd., Golden, CO
80401-3393
303-384-7509 nancy_carlisle@nrel.gov

Energy Efficiency and Renewable Energy Clearinghouse
800-DOE-EREC

Energy Efficiency and Renewable Energy Network (for Internet access to FEMP documents)
HTTP://www.eren.doe.gov

Florida Solar Energy Center
1679 Clearlake Road, Cocoa, FL 32922-5703
407/638-1000 Fax: 407-638-1010

National Association of Energy Service Companies
1440 New York Ave., NW,
Washington, D.C. 2005
202-371-7812 Fax: 202-393-5760

Solar Energy Industries Association (SEIA)
122 C St., NW, 4th Floor, Washington, D.C. 20001
202-383-2600 Fax: 202-383-2670

Solar Rating and Certification Corporation (SRCC)
122 C Street NW, 4th Floor,
Washington, D.C. 20001-2109
202-383-2570

Utility Solar Water-Heating Initiative
c/o Chip Bircher, Wisconsin Public Service Co.
700 N. Adams, Green Bay, WI 54307-9007
414-433-5518 Fax: 414-433-1527

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(512) 345-5446

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*available from FEMP Help Line 800-DOE-EREC

Appendices

Appendix A: Source and Monthly Temperature (°F) at the Source for Cold-Water Supply in 14 Cities [°C=5/9(°F-32)]

(Table 1-1 of ASHRAE's *Active Solar Heating Systems Design Manual.*

	Source*	J	F	M	A	M	J	J	A	S	O	N	D
Albuquerque	W	62	62	62	62	62	62	62	62	62	62	62	62
Boston	Re	32	36	39	52	58	71	74	67	60	56	48	45
Chicago	L	32	32	34	42	51	57	65	67	62	57	45	35
Denver	Ri	39	40	43	49	55	60	63	64	63	56	45	37
Fort Worth	L	46	49	57	70	75	81	79	83	81	72	56	46
Los Angeles	Ri,W	50	50	54	63	68	73	74	76	75	69	61	55
Las Vegas	W	73	73	73	73	73	73	73	73	73	73	73	73
Miami	W	75	75	75	75	75	75	75	75	75	75	75	75
Nashville	Ri	46	46	53	63	66	69	71	75	75	71	58	53
New York	Re	36	35	36	39	47	54	58	60	61	57	48	45
Phoenix	Ri,Re,W	48	48	50	52	57	59	63	75	79	69	59	54
Salt Lake City	W,C	35	37	38	41	43	47	53	52	48	43	38	37
Seattle	Ri	39	37	43	45	48	57	60	68	66	57	48	43
Washington	Ri	42	42	52	56	63	67	67	78	79	68	55	46

*Note that water temperature at point of use may be quite different from this source temperature depending on the municipal distribution system characteristics.

Abbreviations: C — Creek; L — Lake; Re — Reservoir; Ri — River; W — Well

Source data from Handbook of Air Conditioning System Design, pp. 5-41 through 5-46; McGraw Hill Book Company, New York (1965).

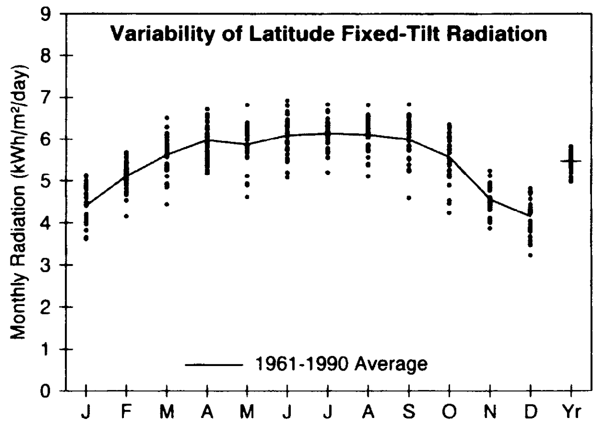
Appendix B:
Example Page from Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors

Boulder, CO

WBAN NO. 94018

LATITUDE: 40.02° N
LONGITUDE: 105.25° W
ELEVATION: 1634 meters
MEAN PRESSURE: 836 millibars

STATION TYPE: Primary



Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	2.4	3.3	4.4	5.6	6.2	6.9	6.7	6.0	5.0	3.8	2.6	2.1	4.6
	Min/Max	2.1/2.7	2.8/3.5	3.7/5.0	4.8/6.1	5.1/7.2	5.7/7.8	5.6/7.4	5.2/6.6	4.0/5.5	3.1/4.2	2.3/2.8	1.9/2.3	4.3/4.8
Latitude -15	Average	3.8	4.6	5.4	6.1	6.2	6.6	6.6	6.3	5.9	5.1	4.0	3.5	5.4
	Min/Max	3.2/4.4	3.8/5.1	4.3/6.2	5.3/6.8	4.9/7.3	5.5/7.6	5.6/7.4	5.3/7.1	4.6/6.7	4.0/5.8	3.4/4.6	2.8/4.1	4.9/5.7
Latitude	Average	4.4	5.1	5.6	6.0	5.9	6.1	6.1	6.1	6.0	5.6	4.6	4.2	5.5
	Min/Max	3.6/5.1	4.2/5.7	4.4/6.5	5.2/6.7	4.6/6.8	5.1/6.9	5.2/6.8	5.1/6.8	4.6/6.8	4.2/6.4	3.9/5.2	3.2/4.8	5.0/5.8
Latitude +15	Average	4.8	5.3	5.6	5.6	5.2	5.2	5.3	5.5	5.8	5.7	4.8	4.5	5.3
	Min/Max	3.9/5.6	4.3/5.9	4.4/6.5	4.8/6.2	4.1/6.0	4.4/5.9	4.5/5.9	4.6/6.2	4.4/6.6	4.2/6.5	4.1/5.6	3.5/5.3	4.8/5.6
90	Average	4.5	4.6	4.3	3.6	2.8	2.6	2.7	3.2	4.0	4.6	4.4	4.3	3.8
	Min/Max	3.6/5.4	3.7/5.2	3.5/5.0	3.0/4.0	2.3/3.1	2.2/2.8	2.3/2.9	2.7/3.6	3.1/4.6	3.4/5.3	3.7/5.1	3.4/5.2	3.4/4.1

Solar Radiation for 1-Axis Tracking Flat-Plate Collectors with a North-South Axis (kWh/m²/day), Uncertainty ±9%

Axis Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	3.7	4.9	6.2	7.6	8.2	9.1	9.0	8.2	7.1	5.7	4.0	3.3	6.4
	Min/Max	3.0/4.4	4.1/5.5	4.6/7.4	6.2/8.7	6.2/10.0	7.4/10.9	7.1/10.2	6.7/9.3	5.3/8.3	4.2/6.6	3.4/4.4	2.6/3.9	5.7/6.9
Latitude -15	Average	4.8	5.9	7.0	8.1	8.4	9.1	9.1	8.6	7.9	6.7	5.0	4.4	7.1
	Min/Max	3.8/5.6	4.8/6.7	5.1/8.4	6.6/9.2	6.3/10.2	7.4/10.9	7.1/10.3	7.0/9.8	5.8/9.2	4.8/7.8	4.2/5.7	3.3/5.2	6.2/7.6
Latitude	Average	5.2	6.2	7.2	8.0	8.1	8.8	8.7	8.4	7.9	7.1	5.5	4.9	7.2
	Min/Max	4.2/6.2	5.1/7.1	5.2/8.6	6.6/9.2	6.1/9.9	7.1/10.4	6.8/10.0	6.8/9.6	5.8/9.3	5.0/8.2	4.6/6.3	3.6/5.8	6.3/7.8
Latitude +15	Average	5.5	6.4	7.1	7.7	7.7	8.2	8.2	8.0	7.8	7.1	5.7	5.2	7.1
	Min/Max	4.4/6.6	5.2/7.3	5.2/8.6	6.3/8.9	5.8/9.4	6.6/9.8	6.4/9.3	6.5/9.2	5.6/9.1	5.0/8.3	4.8/6.6	3.8/6.2	6.1/7.6

Solar Radiation for 2-Axis Tracking Flat-Plate Collectors (kWh/m²/day), Uncertainty ±9%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
2-Axis	Average	5.6	6.4	7.2	8.1	8.5	9.4	9.2	8.6	8.0	7.1	5.7	5.3	7.4
	Min/Max	4.5/6.7	5.2/7.3	5.2/8.6	6.7/9.3	6.4/10.4	7.6/11.1	7.2/10.5	7.0/9.8	5.8/9.3	5.1/8.3	4.8/6.6	3.9/6.3	6.5/8.0

Direct Beam Solar Radiation for Concentrating Collectors (kWh/m²/day), Uncertainty ±8%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
1-Axis, E-W Horiz Axis	Average	3.5	3.7	3.7	4.0	4.2	5.0	4.9	4.5	4.4	4.3	3.6	3.4	4.1
	Min/Max	2.3/4.6	2.8/4.5	2.1/4.8	2.9/5.0	2.9/5.7	3.5/6.4	3.8/6.1	3.4/5.4	2.8/5.5	2.5/5.2	2.7/4.7	2.0/4.3	3.4/4.5
1-Axis, N-S Horiz Axis	Average	2.6	3.4	4.2	5.3	5.6	6.6	6.5	6.0	5.4	4.3	2.8	2.3	4.6
	Min/Max	1.6/3.4	2.5/4.2	2.2/5.7	3.6/6.4	3.8/7.6	4.8/8.5	4.8/8.1	4.5/7.1	3.4/6.7	2.4/5.3	2.2/3.6	1.3/3.0	3.7/5.1
1-Axis, N-S Tilt=Latitude	Average	3.9	4.5	5.0	5.6	5.5	6.2	6.2	6.1	6.0	5.5	4.1	3.6	5.2
	Min/Max	2.5/5.1	3.4/5.5	2.7/6.6	3.8/6.8	3.7/7.5	4.5/8.0	4.6/7.7	4.6/7.3	3.8/7.6	3.1/6.7	3.1/5.3	2.0/4.6	4.2/5.7
2-Axis	Average	4.1	4.6	5.0	5.7	5.8	6.8	6.7	6.3	6.1	5.6	4.3	4.0	5.4
	Min/Max	2.7/5.4	3.5/5.7	2.7/6.6	3.9/6.9	4.0/7.9	4.9/8.7	4.9/8.3	4.8/7.5	3.8/7.6	3.2/6.8	3.3/5.6	2.2/5.0	4.3/6.0

Average Climatic Conditions

Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	-1.3	0.8	3.9	9.0	14.0	19.4	23.1	21.9	16.8	10.8	3.9	-0.6	10.2
Daily Minimum Temp	-8.8	-6.6	-3.4	1.4	6.4	11.3	14.8	13.8	8.7	2.4	-3.7	-8.1	2.3
Daily Maximum Temp	6.2	8.1	11.2	16.6	21.6	27.4	31.2	29.9	24.9	19.1	11.4	6.9	17.9
Record Minimum Temp	-31.7	-34.4	-23.9	-18.9	-5.6	-1.1	6.1	5.0	-8.3	-16.1	-22.2	-31.7	-34.4
Record Maximum Temp	22.8	24.4	28.9	31.7	35.6	40.0	40.0	38.3	36.1	31.7	26.1	23.9	40.0
HDD, Base 18.3°C	608	492	448	280	141	39	0	0	80	238	433	586	3344
CDD, Base 18.3°C	0	0	0	0	6	71	148	113	35	4	0	0	377
Relative Humidity (%)	55	56	54	50	52	49	48	49	50	49	56	56	52
Wind Speed (m/s)	3.7	3.8	4.1	4.4	4.1	3.8	3.6	3.5	3.4	3.4	3.5	3.6	3.8

Appendix C: Federal Life-Cycle Costing Procedures and the BLCC Software

Federal agencies are required to evaluate energy-related investments on the basis of minimum life-cycle costs (10 CFR Part 436). A life-cycle cost evaluation computes the total long-run costs of a number of potential actions, and selects the action that minimizes the long-run costs. When considering retrofits, sticking with the existing equipment is one potential action, often called the *baseline* condition. The life-cycle cost (LCC) of a potential investment is the present value of all of the costs associated with the investment over time.

The first step in calculating the LCC is the identification of the costs. *Installed Cost* includes cost of materials purchased and the labor required to install them (for example, the price of an energy-efficient lighting fixture, plus cost of labor to install it). *Energy Cost* includes annual expenditures on energy to operate equipment. (For example, a lighting fixture that draws 100 watts and operates 2,000 hours annually requires 200,000 watt-hours (200 kWh) annually. At an electricity price of $0.10 per kWh, this fixture has an annual energy cost of $20.) *Nonfuel Operations and Maintenance* includes annual expenditures on parts and activities required to operate equipment (for example, replacing burned out light bulbs). *Replacement Costs* include expenditures to replace equipment upon failure (for example, replacing an oil furnace when it is no longer usable).

Because LCC includes the cost of money, periodic and aperiodic maintenance (O&M) and equipment replacement costs, energy escalation rates, and salvage value, it is usually expressed as a present value, which is evaluated by

$$LCC = PV(IC) + PV(EC) + PV(OM) + PV(REP)$$

where PV(x) denotes "present value of cost stream x,"
IC is the installed cost,
EC is the annual energy cost,
OM is the annual nonenergy O&M cost, and
REP is the future replacement cost.

Net present value (NPV) is the difference between the LCCs of two investment alternatives, e.g., the LCC of an energy-saving or energy-cost-reducing alternative and the LCC of the existing, or baseline, equipment. If the alternative's LCC is less than the baseline's LCC, the alternative is said to have a positive NPV, i.e., it is cost-effective. NPV is thus given by

$$NPV = PV(EC_0) - PV(EC_1)) + PV(OM_0) - PV(OM_1)) + PV(REP_0) - PV(REP_1)) - PV(IC)$$

or

$$NPV = PV(ECS) + PV(OMS) + PV(REPS) - PV(IC)$$

where subscript 0 denotes the existing or baseline condition,
subscript 1 denotes the energy cost saving measure,
IC is the installation cost of the alternative (note that the IC of the baseline is assumed zero),
ECS is the annual energy cost savings,
OMS is the annual nonenergy O&M savings, and
REPS is the future replacement savings.

Levelized energy cost (LEC) is the effective or blended energy price at which a conservation, efficiency, renewable, or fuel-switching measure becomes cost-effective (NPV >= 0). Thus, a project's LEC is given by

$$PV(LEC*EUS) = PV(OMS) + PV(REPS) - PV(IC)$$

where EUS is the annual energy use savings (energy units/yr). Savings-to-investment ratio (SIR) is the total (PV) savings o a measure divided by its installation cost:

$$SIR = (PV(ECS) + PV(OMS) + PV(REPS))/PV(IC).$$

Some of the tedious effort of life-cycle cost calculations can be avoided by using the Building Life-Cycle Cost software, BLCC, developed by NIST. For copies of BLCC, call the FEMP Help Desk at (800) 566-2877.

Appendix D:
Chickasaw Case Study NIST BLCC Comparative Economic Analysis and Cost Estimate Detail

NIST BLCC: COMPARATIVE ECONOMIC ANALYSIS (version 4.20-95)

BASE CASE: chick1b
ALTERNATIVE: chick1s

PRINCIPAL STUDY PARAMETERS:

ANALYSIS TYPE: Federal Analysis--Energy Conservation Projects
STUDY PERIOD: 25.00 YEARS (JAN 1995 THROUGH DEC 2019)
DISCOUNT RATE: 3.0% Real (exclusive of general inflation)
BASE CASE LCC FILE: CHICK1B.LCC
ALTERNATIVE LCC FILE: CHICK1S.LCC

COMPARISON OF PRESENT-VALUE COSTS

	BASE CASE: chick1b	ALTERNATIVE: chick1s	SAVINGS FROM ALT.
INITIAL INVESTMENT ITEM(S):			
CASH REQUIREMENTS AS OF SERVICE DATE	$0	$7,804	-$7,804
SUBTOTAL	$0	$7,804	-$7,804
FUTURE COST ITEMS:			
ENERGY-RELATED COSTS	$16,650	$0	$16,650
SUBTOTAL	$16,650	$0	$16,650
TOTAL P.V. LIFE-CYCLE COST	$16,650	$7,804	$8,846

NET SAVINGS FROM ALTERNATIVE chick1s COMPARED TO ALTERNATIVE chick1b

Net Savings	=	P.V. of non-investment savings	$16,650
	-	Increased total investment	$7,804
		Net Savings:	$8,846

Note: the SIR and AIRR computations include differential initial costs, capital replacement costs, and resale value (if any) as investment costs, per NIST Handbook 135 (Federal and MILCON analyses only).

SAVINGS-TO-INVESTMENT RATIO (SIR)
FOR ALTERNATIVE chick1s COMPARED TO ALTERNATIVE chick1b

$$\text{SIR} = \frac{\text{P.V. of non-investment savings}}{\text{Increased total investment}} = 2.13$$

ADJUSTED INTERNAL RATE OF RETURN (AIRR)
FOR ALTERNATIVE chick1s COMPARED TO ALTERNATIVE chick1b
(Reinvestment rate = 3.00%; Study period = 25 years)

AIRR = 6.17%

ESTIMATED YEARS TO PAYBACK

Simple Payback occurs in year 9
Discounted Payback occurs in year 10

ENERGY SAVINGS SUMMARY

Energy type	Units	Annual Consumption: Base Case	Alternative	Savings	Life-Cycle Savings
Electricity	kWh	9,394	0	9,394	234,850

Small Comfort Station Solar System Cost Estimate					
Solar Heating System Components	Quantity	Unit	Material	Installation	Total
Differential Controller, 2 sensors	1	ea	80.5	30	110.5
Thermometer 2" dial	3	ea	57.75	67.5	125.25
Fill and drain valve, brass 3/4" connections	1	ea	5	14.95	19.95
Air vent, manual, 1/8" fitting	1	ea	9.35	11.2	20.55
Gate valve, 1"dia, bronze	2	ea	28.3	35.8	64.1
Globe valve, 1"dia, bronze	3	ea	96	53.7	149.7
Vent flashing, neoprene	2	ea	13.3	35.8	49.1
Circulator pump, 1/20 hp	1	ea	109	54	163
Relief valve, pressure relief valve	1	ea	14.25	11.95	26.2
Pipe insulation, urethane, UV cover, 1"wall, 3/4"dia	20	ft.	27.6	63	90.6
Pipe insulation, fiberglass, jacketed, 1" wall, 3/4"dia	50	ft.	32.5	142	174.5
Pipe, copper type M, 3/4"dia;, soldered, hung 10"	70	ft.	97.3	321.3	418.6
Pipe, copper type L, 3/4" dia., soldered, hung 10"	20	ft.	34.6	94.4	129
Fittings, copper, 3/4"dia	50	ea	40	942.5	982.5
Sensor wire, 22ga., stranded	50	ft.	5.95	17.25	23.2
Check valve, bronze, 3/4"	1	ea.	23	17.9	40.9
Tempering Valve, bronze, 3/4"	1	ea.	40.5	17.9	58.4
Flow Control Valve	1	ea.	35	16.3	51.3
Storage Tank(s), 500 gallons,Immersed heat exch.	1	ea	1580	155	1735
Collector mounting clamps	4	set	63.6	35.6	99.2
Solar Collectors,4'x12.5', 3/16" glass, sel.surf.	4	ea	3465.6	385.32	3850.92
Design				414.59	414.59
Subtotals			5859.1	2937.96	8797.06
City Cost Adjustments			0.998	0.666	
TOTAL SYSTEM COST			5847.382	1956.681	7804.063

Appendix E:
Sample Specifications for a Drain-Back System from Chickasaw National Recreation Area Case Study

SECTION 15540 SOLAR WATER HEATING SYSTEM

PART 1: GENERAL

1 DESCRIPTION: The work of this section consists of designing, furnishing, and installing a new drain back solar energy system for the heating of service water using roof-mounted, single glaze, flat plate liquid solar collectors. Control the system by a simple differential temperature controller. Include with the system a monitoring system to monitor system operation. Design a drain back type system so that when the collector pump is not operating, the heat transfer fluid drains back into a insulated drain back heat exchanger tank to provide freeze proof operation and prevent overheated fluid. Provide a solar system which will be the only water-heating system for the building with no auxiliary water-heating system.

Include with the system, components that consist of a solar collector array, drain back tank, storage tank, pumps, automatic controls, instrumentation, interconnecting piping and fittings, tempering mixing valve, heat exchanger, energy delivery performance monitoring system and all other accessories and equipment required for the proper operation of the solar system.

1 RELATED WORK: General mechanical provisions - Section 15010; basic materials and methods - Section 15050; pipe and equipment insulation - Section 15260; plumbing systems - Section 15400; plumbing fixtures - Section 15440.

1 DEFINITIONS - The term "solar" for the purposes of this section, relates to systems that convert solar radiation to thermal energy. The thermal energy is collected by a heat transfer fluid and sent to a thermal energy storage tank for use.

1 QUALITY ASSURANCE:

Meet requirements of the 1990 BOCA plumbing code.

Installation Contractor shall be regularly engaged in the installation of solar heated hot water systems of the type required for this project.

Furnish materials and equipment that are the standard products of a manufacturer regularly engaged in the manufacture of such products, and which duplicate items that have been used satisfactorily on previous projects.

1 PERFORMANCE REQUIREMENTS: Systems shall be designed according to the following performance criteria. Hot water demand will be highest during the months of May through September. Systems shall be able to accommodate prolonged periods of inoperation with no starting procedures and no damage to the system as a result of stagnation.

Large Comfort Station: Design and size the system so that solar energy supplies at least 65 GJ (18,000 KWH) per year. Any remaining load will go unmet when sunlight is insufficient or unavailable.

The following parameters shall be used to design and size the system:

Expected daily hot water use: 1500 gallons per day.

Tempered hot water delivery temperature: at least 105°F at shower heads.

Approximate temperature of input water supply: 60°F.

Hot water is needed for showers, lavatories and cleaning.

1 SUBMITTALS: As specified in Section 01300. Submit for approval complete data and shop drawings on the following items:

Approval Drawings and Data:

Commercial Products Data with Performance Charts and Curves. Annotate descriptive data to show the specific model, type, and size of each item.

Solar System Design. Submit calculations of solar System design. Calculations shall support system sizing consistent with the Performance Requirements described above.

Certification from the metal roof manufacturer that solar collector mounting system is compatible with metal roof system and will not affect the roof system warranty.

Drawings: Submit shop drawings for the system containing a system schematic; a collector layout and roof plan noting reverse-return piping for the collector array and drain-back without water traps for the array and associated piping, a system elevation; a mechanical equipment room layout; a schedule of operation and installation instructions; and a schedule of design information including collector height and width, recommended collector flow rate and pressure drop at that flow rate, number of collectors, number of collectors to be grouped per bank, gross area and net aperture area of collectors, collector fluid volume, collector filled weight, weight of support structure, and tilt angle of collectors from horizontal. Include in the drawings, complete wiring and schematic diagrams, proposed pipe pitch and any other details required to demonstrate that the system has been coordinated and will properly function as a unit. Show proposed layout and anchorage of equipment and appurtenances, and equipment relationship to other parts of the work, including clearances for maintenance and operation. Provide layout and details of the solar collector mounting brackets and the connections to the roof system. Coordinate mounting bracket connections with metal roof system manufacturer.

1 CLOSEOUT SUBMITTALS: As specified in Section 01730. Submit the following items at the completion of the project:

Posted Instructions: Submit for review, typed copies of proposed; diagrams, instructions, and other sheets, prior to posting in the building's mechanical room. Include a system schematic, and wiring and control diagrams showing a layout of the entire system. Include with the instructions, in typed form, framed or laminated and posted beside the diagram condensed operating instructions summarizing preventive maintenance procedures, design flow rates, methods of checking the system for normal safe operation and procedures for safely starting and stopping the system, methods of balancing and testing flow in the system, and methods of testing for control failure and proper system operation. Post all framed instructions prior to the date of the system acceptance.

Operating and Maintenance Manuals: Submit manuals that detail the step-by-step procedures required for system filling, startup, operation, and shutdown. Include in the manuals the manufacturer's name, model number, service manual, parts list, and brief descriptions of all equipment and their basic operating features. List routine maintenance procedures, possible breakdowns and repairs, recommended spare parts, troubleshooting guides, piping and equipment layout, balanced fluid flow rates, and simplified wiring and control diagrams of the system as installed. Refer to ASHRAE 90336 Guidance For Preparing Active Solar Heating Systems Operation and Maintenance Manuals for guidance in preparing the Operation and Maintenance manuals, with exceptions for aspects of the proposed system which are not addressed in ASHRAE 90336.

Field Test Reports: Submit field test reports after final system testing.

Warranties: Provide manufacturers warranties on all components supplied.

PART 2: PRODUCTS

2 GENERAL: Solar water-heating system shall be supplied and installed by one of the following firms, or an approved equal:

1. Solar System Installations
   726 Meadow Glen Circle
   Coppell, TX 75019
   Attn: Phillip Fisher, 214-462-0626
2. Sun Trapper Solar Systems
   12118 Radium
   San Antonio, TX 78216
   Attn: Michaele, or Rick Fossum, 210-341-2001; FAX 210-341-2652

3. The Solar Doctors
9005 Craig Drive
DeSoto, KS 66018
Attn: Mike Myers, 913-583-1398

4. Solar Master
P.O. Box 11635
Albuquerque, NM 87192
Attn: Odes Caster, 505-766-9041

2 SOLAR WATER HEATING SYSTEM:

General: Provide a drain back type solar water-heating system with a closed loop on the solar side of the heat exchanger. This system shall be as described in part I of this section with building interface attachments, plumbing and venting in accordance with the drawings.

Piping: Provide a piping system complete with pipe, pipe fittings, valves, strainers, expansion loops hangers, inserts, supports, anchors, guides, sleeves, and accessories in accordance with drawings and specifications. Design flow rates shall be below 5 feet per second. Piping shall be identified with fluid type and flow direction labels.

Pipe: Type "M" copper, ASTM-88-95.

Fittings: Sweat-type wrought copper. Solder for all piping shall be silver type with no lead or antimony content and a melting point of not less than 440°F (B-melt). Silvabrite 100 95.5 tin/ 4 copper/ 0.5 silver as manufactured by Engelhard Corporation, Mansfield, MA 02048, (508) 339-0589 or approved equal.

Provide unions or flanges at the junction of major equipment components such as heat exchangers, mixing valve etc., on the potable water side of the system. No unions or flanges are permitted in the solar loop. Provide di-electric unions for connections from copper pipe to steel pipe or fittings.

Hangers, Supports and Guides: Section 15400.

Calibrated Balancing Valves - Provide calibrated balancing valves suitable for 125 psig and 250°F service. Balancing valves shall be, bronze body/brass ball construction with seat rings compatible with system fluid and differential readout ports across valve seat area. Readout ports shall be fitted with internal insert of compatible material and check valve. Valves shall be provided with a memory stop feature to allow valve to be closed for service and reopened to set point without disturbing balance position, and with a calibrated nameplate to assure specific valve settings.

Provide ball valves at the outlet of each collector bank. If multiple collector banks are proposed, provide calibrated balancing valves for each bank. The balancing valves are required to allow the array to be flow balanced. The ball valves are necessary to enable the array to be disconnected for maintenance or repair.

Pressure Gauges shall be throttling type needle valve or a pulsation dampener and shutoff valve. Furnish a 3-1/2 inch minimum dial size.

Thermometers shall be provided with wells and separable bronze sockets.

Insulation: Section 15260.

Solar Collector Panels:

Panels shall be Solar Rating and Certification Corporation (SRCC) -tested, single glazed, flat plate, for roof mounting in a drain back system configuration. Collector shall be weather-tight construction with a bronze anodized aluminum casing. Absorber plate shall have black chrome, nickel or other selective coating, absorber flow passages shall be copper. Tubes on the absorber plate shall drain by gravity. Glazing shall be low iron tempered glass, textured to reduce glare, completely replaceable from the front of the collector without disturbing the piping or adjacent collectors. Risers, manifolds and external connectors shall be copper. Frame shall be assembled with stainless steel screws. Dimensions of each collector are not to exceed 4'- 0" x 12'- 9".

Collector Warranty - Provide a minimum 10-year warranty against the following: failure of manifold or riser tubing, joints or fittings; degradation of absorber plate selective surface; rusting or discoloration of collector hardware; and embrittlement of header manifold seals. Include with the warranty full repair or replacement of defective materials or equipment.

Solar Collector Performance - Plot thermal performance on the thermal efficiency curve in accordance with ASHRAE 93. Show manufacturer's recommended volumetric flow rate and the design pressure drop at the recommended flow rate. Indicate the manufacturer's recommendations for the number of collectors to be joined per bank while providing for balanced flow and for thermal expansion considerations.

Solar Collector Array:

Connect interconnecting array piping between solar collectors in a reverse-return configuration with approximately equal pipe length for any possible flow path. Indicate flow rate through the collector array. Provide each collector bank isolated by valves, with a pressure relief valve and with the capability of being drained. Locate manually operated air vents at system high points, and pitch array piping a minimum of 0.25 inch per foot so that piping can be drained by gravity. Collectors must also be mounted to drain by gravity. Supply calibrated balancing valves at the outlet of each collector bank as indicated.

Supports for solar collector array shall be of aluminum or stainless steel construction and provide support structure for the collector array. Support structure shall secure the collector array at the proper tilt angle with respect to the horizontal and provide correct orientation with respect to true south. Support structure shall withstand the static weight of filled collectors and piping plus 20 PSF of applied gravity load. Support structure shall withstand 30 PSF of collector surface uplift due to wind, 0.3 times the weight of the collectors lateral load due to seismic motions, and other anticipated loads without damage. Design of support structure shall allow access to all equipment for maintenance, repair, and replacement. EPDM or neoprene washers shall separate all dissimilar metals. Supports shall transfer loads to the roof rafters. Supports shall not adversely affect the performance of the metal roof system.

Solar Preheat Storage Tank - Provide an above ground, vertical cylindrical thermal energy storage solar preheat tank with a storage capacity of at least 1000 gallons, approximately 4'- 0" diameter x 11'-6" high for the comfort station. Insulate each tank with fiberglass or foam with a loss coefficient of not less than R-19. Protect the insulation by a PVC or steel jacket.

If the design calls for storage of pressurized potable water, the tank shall be rated at 100 lb/in^2 at 190°F, with the interior of each tank lined for potable service. Storage tanks shall be protected from corrosion with coatings, dielectric unions, and possible sacrificial anodes. Storage tanks shall be of a size capable of moving through the mechanical room doors.

Transport Subsystem:

Heat Exchanger - Minimum design pressure rating of 100 psi. Construct heat exchanger of 316 stainless steel, titanium, copper-nickel, or brass. Furnish heat exchanger with a capability of withstanding temperatures of at least 240°F. The heat exchanger from heat transfer fluid to potable water may be in a drainback module or may be a coil in the preheat storage tank if the heat transfer fluid drains back into the preheat storage tank. Hot water supply loop heat exchanger shall be of double wall construction with positive leak detection, if glycol or other chemicals are used in the solar loop of the system. A single wall heat exchanger is acceptable if; the tank and makeup water inlets are labeled as, "potable water only"; and the collector loop fluid consists of purified water, with only non-toxic, food-grade additives to prohibit corrosion.

Pumps shall be electrically-driven, single-stage, centrifugal type circulating pumps such as manufactured by Grundfos Pumps Corp., Clovis, CA 93612 or approved equal. Provide necessary support for pumps. Provide vibration isolation between pumps, piping systems, and building structure. The pump shaft shall be constructed of corrosion resistant alloy steel with a mechanical seal. Provide stainless steel impellers and casings of bronze. Control motors with switches that can be activated by either the differential temperature controller or by manual override (Hand-Off-Automatic).

Heat Transfer Fluid. Provide potable distilled, deionized water with non-toxic corrosion inhibitors as the solar collector loop fluid. Propylene Glycol should be added for additional freeze protection if the drainback module is not the preheat storage tank.

Control and Instrumentation Subsystem:

Energy Delivery Performance Monitoring Equipment -Include with each solar system simple methods for assessing system operational status. Monitoring system may be integrated with system controller as described below. Government will provide a Btuh meter for installation by contractor.

Differential Temperature Control Equipment - Furnish the differential temperature control equipment as a system from a single manufacturer. Furnish a solid-state electronic type controller complete with an integral transformer to supply low voltage. Controller accuracy shall be plus or minus 1°F. Supply controllers that are compatible with the thermistor temperature sensors. Provide differential controls with direct digital temperature readings of all temperatures sensed. Supply controls with a visual indicator when pumps are energized. Provide a controller which will identify open and short circuits on both the solar collector temperature sensor circuit and the storage tank sensor circuit. Provide a controller with storage high limit function to avoid collection of heat during stagnation conditions.

Thermistor Temperature Sensors - Provide temperature sensors that are compatible with the differential temperature controller, with an accuracy of plus or minus 1 percent at 77°F. Sensors shall have passed an accelerated life test conducted by subjecting thermistor assemblies to a constant temperature of 400 °F or greater for a period of 1000 hours minimum with an accuracy of within plus or minus 1 percent as stated above. Thermistors shall be of hermetically sealed glass construction. Provide immersion wells or watertight threaded fittings for temperature sensors.

Water Mixing Valve: Section 15400

Painting and Finishing - Furnish equipment and component items, with the factory applied manufacturer's standard finish.

PART 3: EXECUTION

3 PIPING: Install and connect all piping necessary for a complete and functional system in compliance with the drawings, specifications, and approved shop drawings.

All piping shall be run straight and parallel to building construction unless otherwise shown. All changes in direction shall be made with fittings as specified herein or shown on the plans. Install piping straight and true to bear evenly on hangers and supports. Hang horizontal runs from ceilings or structure above the ceiling. Keep piping systems clean during installation by means of plugs or other approved methods. Discharge storage tank pressure and temperature relief valves into floor drains. Provide air vents with threaded plugs or caps.

Soldering of Pipe:

1. Ends of pipe shall be cleaned with sand cloth so as to remove all oxides before soldering. Fittings shall be similarly cleaned with emery cloth.

2. Silver brazing flux shall be used when flux is required.

3. Solder shall completely fill all parts of joint.

Install copper plated supports and/or hangers to prevent sags, bends, or vibration; in any case, provide within 6 inches of elbows and valves, at end of all branches over 5 feet, and on centers not exceeding the following: Copper tubing - up to 1 inch diameter, 6 feet; over 1 inch diameter, 8 feet.

Install pipe insulation finishes tightly and neatly without wrinkles, bulges, tears, or raw edges. All joints shall be thoroughly sealed.

3 SOLAR WATER HEATING SYSTEM:

Control and Sensor Wiring: Install control and sensor wiring in conduit. Install Government provided Btuh meter.

Collector Array: Install solar collector array at the proper tilt angle, orientation, and elevation on the south-facing roof. Install the solar collectors with the ability to be removed and reinstalled for maintenance, repair, or replacement.

Array Piping: Install collector array piping in a reverse-return configuration so that path lengths of collector supply and return are of approximately equal length.

Array Support: Install array support in accordance with the recommendations of the collector manufacturer and the metal roof system manufacturer.

Pipe Expansion: Provide for the expansion and contraction of supply and return piping with changes in the direction of the run of pipe or by expansion loops. Do not use expansion joints in the system piping.

Valves: Install ball valves at the inlet and outlet of each bank of internally manifolded collectors. The ball valves are intended for system shut-down and or isolation of particular elements of the system during maintenance procedures. Install calibrated balancing valves at the outlet of each collector bank and mark final balance settings on each valve. Install a union adjacent to each ball valve. Balance flow through the collector piping with at least one balancing valve left in the open position. Locate tempering mixing valve as shown on the drawings to control hot water delivery temperature.

3 IDENTIFICATION: Secure to each major item of equipment using weather resistant nameplates the manufacturer's name, address, phone number, type or style, model or serial number, and catalog number.

3 OPERATING INSTRUCTIONS: As specified in Section 01700. Post framed instructions under glass or in laminated plastic in each building mechanical room. Include in these instructions a system schematic, and wiring and control diagrams showing the complete layout of the solar water-heating system. Prepare condensed operating instructions explaining preventative maintenance procedures, balanced flow rates, methods of checking the system for normal safe operation, and procedures for safely starting and stopping the system, in typed form, framed as specified above, and posted beside the diagrams. Post the framed instructions before acceptance testing of each system.

3 ACCEPTANCE TESTING AND FINAL INSPECTION: Maintain a written record of the results of all acceptance tests, to be submitted in booklet form. Provide the following tests:

Hydrostatic Test: Section 15992, Domestic Water.

Operational Test: Test operation of each system over a period of 2 days with sufficient solar insolation during the day to cause activation of the solar energy system control and circulation functions.

Overall System Operations: Demonstrate each solar energy system will operate properly while unattended for a period of at least 72 hours. Demonstrate the system controller will start the pumps after being warmed by the sun, and that it will properly shut down during cloudy weather or in the evening over a minimum of three complete cycles. It is permissible to manipulate the temperature of the storage tank by the introduction of cold water.

Temperature Sensor Diagnostics: Demonstrate the controller will correctly identify open and short circuits on both the solar collector temperature sensor circuit and the storage tank sensor circuit.

3 TESTING AND DISINFECTION: Section 15400.

3 DEMONSTRATION: As specified in section 01670. The government operating personnel shall receive a minimum of 8 hours of operational instruction on the solar water-heating system.

Provide a field training course for operating and maintenance staff members after the system is functionally complete. Include in the training a discussion of the system design and layout; and demonstrate routine operation, maintenance and troubleshooting procedures.

PART 4: MEASUREMENT AND PAYMENT

4 SOLAR WATER HEATING SYSTEM: Payment will be included in the lump-sum price for the Comfort Station.

END

Appendix F: Data Necessary for Evaluating Solar Water-Heating Systems

A. Building hot water requirements

1. Daily Load ______________gal/day (L/day) maximum,

   ______________gal/day (L/day) minimum

   How determined? ____

2. Daily use pattern ____
3. Hot water delivery temperature ____________°F (°C)
4. Load profile [list monthly hot water load estimates, gallons (litres)]:

   Jan ______ Feb ______ Mar ______ Apr ______ May ______ Jun ______

   Jul ______ Aug ______ Sep ______ Oct ______ Nov ______ Dec ______

5. Total annual load ______________

B. Main heating system

1. Energy source: Gas _______ Electric _______ Oil _______ Steam ______

   Cost ________

2. Hot water heater/storage capacity ______________gallon

   How water heater efficiency _____________

3. Hot water circulation: Yes _______ No _______
4. Cold water temperature _______°F (°C) maximum _______°F (°C) minimum

C. Building information

Date of construction ______________

Building name____

Location (including Zipcode)____

1. Primary building use: ____
2. Number of floors: ______________ Total floor area _____________ ft^2 (m^2)
3. Utilities available:

   Natural gas _____________ Propane gas ___________ Fuel oil __________

   Electric: ______________ volt, ______________ phase, __________ kW

4. Water quality: pH ______________ Dissolved solids ______________ ppm

D. Collector and storage locations

1. Potential collector location: Roof _______ Ground _______ Wall _______

   If roof, type: Flat ___________ Pitched ___________

   If pitched, pitch line direction (azimuth of compass direction roof faces) _______

   and slope ___________

   Roofing material ____

   Area available for collectors _________ ft (mm [N/S] x ________ ft (mm) [E/W]

   Potential shading problems ____

   Provide sketch showing shape and overall dimensions of potential collector locations and orientations with location and type of any obstructions of potential shading sources.

2. Potential storage location: Indoor ___________ Outdoor ___________

   If indoor, available area ___________ ft (mm) x ___________ ft (mm);

   Ceiling height ___________ ft (mm)

   Access to storage location: ___________ door sizes ___________ other

3. Potential mechanical equipment location: Indoor ___________

   Outdoor ___________

   If indoor, available area ___________ ft (mm) x ___________ ft (mm)

4. Approximate distance collector to heat exchanger or storage _________ ft (mm)

   elev,___________ ft (mm) horizontal

5. Approximate distance heat exchanger to storage ________ ft (mm) elev,

   ______ ft (mm) horizontal

Appendix G:
SRCC Rating Page for Flat-Plate Collector

SOLAR COLLECTOR CERTIFICATION AND RATING	**CERTIFIED SOLAR COLLECTOR**
	SUPPLIER: **Acme Solar** 1300 Sunshine Lane Los Angeles, CA 65551
SRCC OG-100	MODEL: Sun Grabber 1800 COLLECTOR TYPE: Glazed Flat-Plate CERTIFICATION #: 100-95-100A

COLLECTOR THERMAL PERFORMANCE RATING

Megajoules Per Panel Per Day				Thousands of Btu Per Panel Per Day			
CATEGORY (Ti-Ta)	CLEAR DAY 23 $MJ/m^2 \cdot d$	MILDLY CLOUDY 17 $MJ/m^2 \cdot d$	CLOUDY DAY 11 $MJ/m^2 \cdot d$	CATEGORY (Ti-Ta)	CLEAR DAY 2000 $Btu/ft^2 \cdot d$	MILDLY CLOUDY 1500 $Btu/ft^2 \cdot d$	CLOUDY DAY 1000 $Btu/ft^2 \cdot d$
A (-5 °C)	55	42	28	A (-9 °F)	52	40	27
B (5 °C)	50	37	23	B (9 °F)	47	35	22
C (20 °C)	42	29	16	C (36 °F)	40	28	19
D (50 °C)	26	14	4	D (90 °F)	25	14	4
E (80 °C)	12	3		E (144 °F)	11	3	

A-Pool Heating (Warm Climate) **B**-Pool Heating (Cool Climate) **C**-Water Heating (Warm Climate) **D**-Water Heating (Cool Climate) **E**-Air Conditioning

Original Certification Date: June 15, 1993

COLLECTOR SPECIFICATIONS

Gross Area:	3.71	m^2	40	ft^2	**Net Aperture Area:**	3.6	m^2	38.8	ft^2
Dry Weight:	80	kg	177	lb	**Fluid Capacity:**	5.3	l	1.4	gal
Max. Oper. Pressure:	550	kPa	80	psig	**Max. Oper. Temp.:**	107	°C	225	°F
Max. Wind Load:	2.6	kPa	55	psf					

COLLECTOR MATERIALS

Frame: Acrylic Painted Aluminum
Cover (Outer): Low Iron Tempered Glass
Cover (Inner): None
Absorber Material: Copper
Absorber Coating: Flat Black Paint
Insulation (Side): 1 in. Polyisocyanurate
Insulation (Back): 1 in. Polyisocyanurate

PRESSURE DROP

Flow		Δ P	
ml/s	**gpm**	**Pa**	**in H_2O**
88.33	1.40	3450.00	13.85

TECHNICAL INFORMATION

Efficiency Equation [NOTE: (P) = Ti-Ta]

		Y Intercept	Slope	
S I Units:	$\eta = 0.644 \quad -6.269 \quad (P)/I \quad -0.004 \quad (P)^2/I$	0.646	-6.609	$W/m^2 \cdot °C$
I P Units:	$\eta = 0.644 \quad -1.105 \quad (P)/I \quad -0.0004 \quad (P)^2/I$	0.646	-1.165	$Btu/hr \cdot ft^2 \cdot °F$

Incident Angle Modifier [NOTE: (S) = 1/cos θ - 1]

$K_{\alpha\tau} = 1.0 \quad -0.204 \quad (S) \quad -0.0073 \quad (S)^2$

Model Tested: 1600
Test Fluid: Water
Test Flow Rate: 90 ml/s 1.43 gpm

REMARKS:

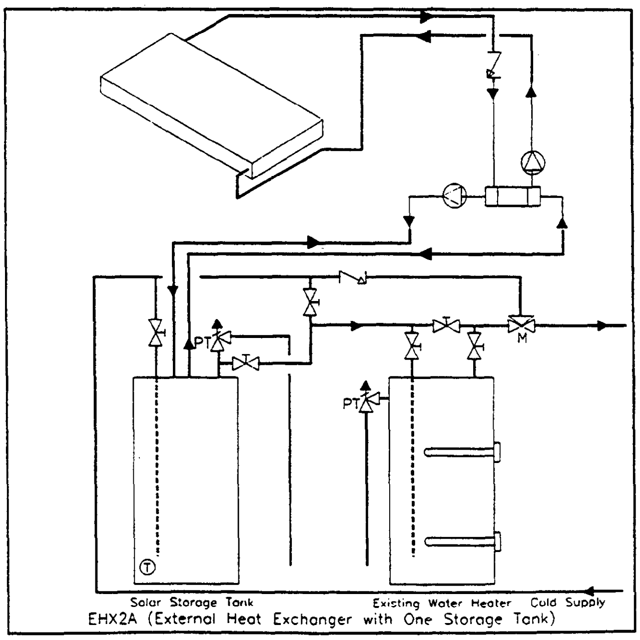
December 1995
Certification must be renewed annually. For current status contact:
SOLAR RATING & CERTIFICATION CORPORATION
122 C Street ♦ 4th Floor ♦ Washington, DC 20001-2670 ♦ (202) 383-2570 ♦ Fax (202) 383-2670

Appendix H:
SRCC Rating Page for Antifreeze System

SOLAR WATER HEATING SYSTEMS CERTIFICATION AND RATING	**CERTIFIED SOLAR WATER HEATING SYSTEM**
	SUPPLIER: Sunny Solar Products 1300 Sunshine Lane Reno, NV 79960 (567) 200-2345 (567) 200-7890 (fax) (800) 123-6567
SRCC OG-300	SYSTEM NAME: Solar HX SYSTEM TYPE: Indirect Forced Circulation System

Description: Glazed Flat-Plate Collector, Differential Controller, Double Wall HX W/ Double Wall and Positive Leak Detection, No Load Side Heat Exchanger, Fluid class II.

System Model Name	Cert. 300-#	Cert. Date	Collector Panel Manufacturer	Collector Panel Name	Total Panel Area (m^2)	Total Panel Area (ft^2)	Solar Tank Vol. (l)	Solar Tank Vol. (Gal)	Aux. Tank Vol. (l)	Aux. Tank Vol. (Gal)	**SEF**
Biggie	95200A	9/02/95	Acme Solar	410C	3.7	40	303	80	189	50	2.7
Standard	95200B	9/02/95	Acme Solar	408C	2.9	32	227	80	189	50	1.8



EHX2A (External Heat Exchanger with One Storage Tank)

December 1995

Certification must be renewed annually. For current status contact:

SOLAR RATING & CERTIFICATION CORPORATION

122 C Street ♦ 4th Floor ♦ Washington, DC 20001-2670 ♦ (202) 383-2570 ♦ Fax (202) 383-2670

Appendix I:
SRCC Rating Page for Drain-Back System

SOLAR WATER HEATING SYSTEMS CERTIFICATION AND RATING

SRCC OG-300

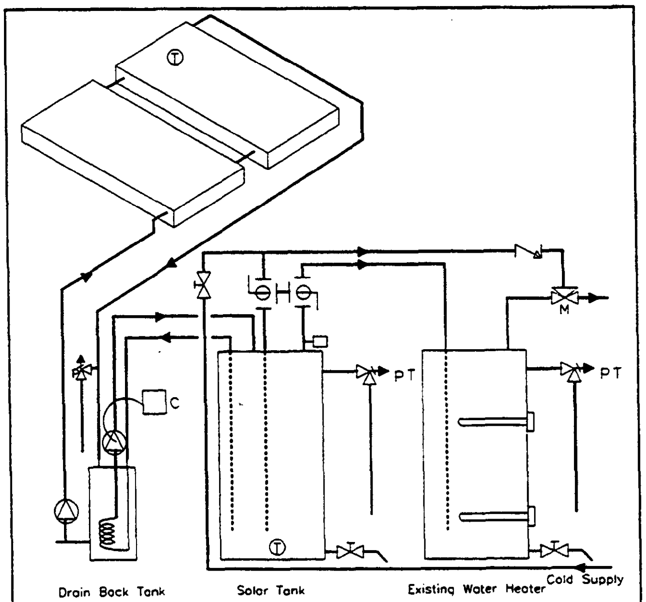
CERTIFIED SOLAR WATER HEATING SYSTEM

SUPPLIER: Good Solar Products
1300 Sunshine Lane
Miami, FL 39960
(567) 989-2345
(567) 989-7890 (fax)
(800) 123-4567

SYSTEM NAME: Drain Back Heat Exchanger
SYSTEM TYPE: Indirect Forced Circulation System

Description: Glazed Flat-Plate Collector, Differential Controller, Immersed Coil Supply Side Heat Exchanger with a Single Wall, No Load Side Heat Exchanger, Fluid class I.

System Model Name	Cert. 300-#	Cert. Date	Collector Panel Manufacturer	Collector Panel Name	Total Panel Area (m^2)	Total Panel Area (ft^2)	Solar Tank Vol. (l)	Solar Tank Vol. (Gal)	Aux. Tank Vol. (l)	Aux. Tank Vol. (Gal)	**SEF**
80-120-I	95100A	9/02/95	Acme Solar	410A	7.43	80	455	120	189	50	2.3
80-80-I	95100B	9/02/95	Acme Solar	408A	5.94	64	303	80	189	50	1.5



DBC2A (Drain Back System W/ 2 Tanks)

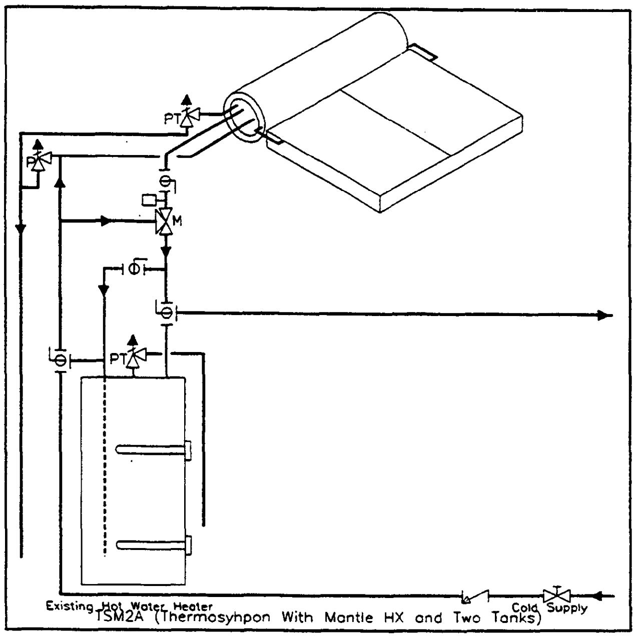
December 1995
Certification must be renewed annually. For current status contact:
SOLAR RATING & CERTIFICATION CORPORATION
122 C Street ♦ 4th Floor ♦ Washington, DC 20001-2670 ♦ (202) 383-2570 ♦ Fax (202) 383-2670

Appendix J:
SRCC Rating Page for Thermosiphon System

SOLAR WATER HEATING SYSTEMS CERTIFICATION AND RATING	CERTIFIED SOLAR WATER HEATING SYSTEM
SOLAR SRCC CERTIFICATION ®	SUPPLIER: Fine Solar Products 2300 Sunshine Lane Phoenix, AZ 83522 (867) 989-7345 (867) 989-7890 (fax) (800) 125-4867
SRCC OG-300	SYSTEM NAME: Syphon Max SYSTEM TYPE: Indirect Thermosyphon

Description: Glazed Flat-Plate Collector, Mantle Heat Exchanger with a Single Wall, No Load Side Heat Exchanger, Fluid Class II.

System Model Name	Cert. 300-#	Cert. Date	Collector Panel Manufacturer	Collector Panel Name	Total Panel Area (m^2)	Total Panel Area (ft^2)	Solar Tank Vol. (l)	Solar Tank Vol. (Gal)	Aux. Tank Vol. (l)	Aux. Tank Vol. (Gal)	**SEF**
80-120-50-TS	95101A	9/02/95	Acme Solar	410B	7.51	80.8	303	80	189	50	1.8
80-80-50-TS	95101B	9/02/95	Acme Solar	408B	6.15	66.2	303	80	189	50	1.2



December 1995
Certification must be renewed annually. For current status contact:
SOLAR RATING & CERTIFICATION CORPORATION
122 C Street ♦ 4th Floor ♦ Washington, DC 20001-2670 ♦ (202) 383-2570 ♦ Fax (202) 383-2670

About the Federal Technology Alerts

The Energy Policy Act of 1992, and subsequent Executive Orders, mandate that energy consumption in the Federal sector be reduced by 30% from 1985 levels by the year 2005. To achieve this goal, the U.S. Department of Energy's Federal Energy Management Program (FEMP) is sponsoring a series of programs to reduce energy consumption at Federal installations nationwide. One of these programs, the New Technology Demonstration Program (NTDP), is tasked to accelerate the introduction of new energy-saving technologies into the Federal sector and to improve the rate of technology transfer.

As part of this effort, FEMP, in a joint venture with the Department of Defense's Strategic Environmental Research and Development Program (SERDP), is sponsoring a series of Federal Technology Alerts (FTAs) that provide summary information on candidate energy-saving technologies developed and manufactured in the United States. The technologies featured in the Technology Alerts have already entered the market and have some experience but are not in general use in the Federal sector. Based on their potential for energy, cost, and environmental benefits to the Federal sector, the technologies are considered to be leading candidates for immediate Federal application.

The goal of the Technology Alerts is to improve the rate of technology transfer of new energy-saving technologies within the Federal sector and to provide the right people in the field with accurate, up-to-date information on the new technologies so that they can make educated judgments on whether the technologies are suitable for their Federal sites.

Because the Technology Alerts are cost-effective and timely to produce (compared with awaiting the results of field demonstrations), they meet the short-term need of disseminating information to a target audience in a timeframe that allows the rapid deployment of the technologies—and ultimately the saving of energy in the Federal sector.

The information in the Technology Alerts typically includes a description of the candidate technology; the results of its screening tests; a description of its performance, applications and field experience to date; a list of potential suppliers; and important contact information. Attached appendixes provide supplemental information and example worksheets on the technology.

FEMP sponsors publication of the Federal Technology Alerts to facilitate information-sharing between manufacturers and government staff. While the technology featured promises significant Federal-sector savings, the Technology Alerts do not constitute FEMP's endorsement of a particular product, as FEMP has not independently verified performance data provided by manufacturers. FEMP encourages interested Federal energy and facility managers to contact the manufacturers and other Federal sites directly, and to use the worksheets in the Technology Alerts to aid in their purchasing decisions.

Federal Energy Management Program

The Federal Government is the largest energy consumer in the nation. Annually, in its 500,000 buildings and 8,000 locations worldwide, it uses nearly two quadrillion Btu (quads) of energy, costing over $11 billion. This represents 2.5% of all primary energy consumption in the United States. The Federal Energy Management Program was established in 1974 to provide direction, guidance, and assistance to Federal agencies in planning and implementing energy management programs that will improve the energy efficiency and fuel flexibility of the Federal infrastructure.

Over the years several Federal laws and Executive Orders have shaped FEMP's mission. These include the Energy Policy and Conservation Act of 1975; the National Energy Conservation and Policy Act of 1978; the Federal Energy Management Improvement Act of 1988; and, most recently, Executive Order 12759 in 1991, the National Energy Policy Act of 1992 (EPACT), and Executive Order 12902 in 1994.

FEMP is currently involved in a wide range of energy-assessment activities, including conducting New Technology Demonstrations, to hasten the penetration of energy-efficient technologies into the Federal marketplace.

Strategic Environmental R&D Program

The Strategic Environmental Research and Development Program, SERDP, co-sponsor of these Federal Technology Alerts, was created by the National Defense Authorization Act of 1990 (Public Law 101-510). SERDP's primary purpose is to "address environmental matters of concern to the Department of Defense and the Department of Energy through support for basic and applied research and development of technologies that can enhance the capabilities of the departments to meet their environmental obligations." In 1993, SERDP made available additional funds to augment those of FEMP, for the purpose of new technology installations and evaluations.

FEMP
FEDERAL ENERGY MANAGEMENT PROGRAM

For More Information

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Help Line (800) DOE-EREC

FEMP Federal Renewables Program
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